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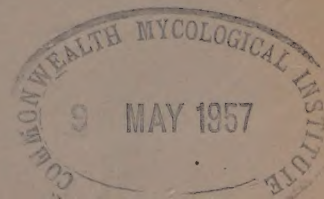
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SOME FACTORS CAUSING BLINDNESS IN EARLY SUMMER CAULIFLOWERS

By BARBARA W. L. MOUNSEY-WOOD

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In the 1948-9 variety trials of early summer cauliflowers at Kirton, it was observed that there was more blindness in Remme than in any of the other varieties. It had also been noted previously that, in certain years, complaints of blindness in commercial crops of Remme and its named selections had been received from the surrounding districts. In one particular instance the blindness had been as high as 95 per cent. A questionnaire dealing with blindness was, therefore, sent to interested officers of the National Agricultural Advisory Service and replies showed that blindness in Remme and its selections was widespread and that it was most serious in areas north of the Thames. The amount of blindness progressively increased towards the northern counties and was particularly severe where sowings of cauliflower were delayed until October.

As a result of these observations it was decided to investigate the effects of various sowing and planting dates on early cauliflower and, as Remme appeared to be rather more susceptible to blindness than other varieties, to use this variety for the trial. Different planting dates were introduced into the trial so that plants from different sowing dates, but of the same age group, could be compared. While the main object of the experiment was to determine the effect on blindness, the practical effects of sowing and planting dates on crop yield and quality were also investigated. The practice on the farm at Kirton had been to sow cauliflower seed early in October but, in view of the answers to the questionnaire, it was decided that the sowing dates should extend from mid-September to mid-October. It was also realized that blindness in cauliflower could be caused by molybdenum deficiency as described by Hewitt and Jones (1947), although Wiebosch *et al.* (1950) in Holland had shown that environmental conditions could also influence the amount of blindness. The latter distinguished two groups of symptoms which they named "whiptails" (not due to molybdenum deficiency) and "common blindness" which is similar to the disorders noted in Remme. In 1953 Smith observed the effect of low temperature on the incidence of blindness in over-wintering plants but she gave no details.

EXPERIMENTAL PROCEDURE.

In the first two years of the experiment (1949-51), the stock of seed of Remme was the same as that which had been used in the variety trials in 1948-9. For the rest of the trial period (1951-3) a fresh stock of seed had to be obtained which was unrelated to the original one.

Sowing dates.

In 1949-50 three separate sowings were made at fortnightly intervals starting on 20th September. After one year's work, however, it was obvious that plants from the last sowing (19th October) were too small for planting out in the spring and consequently, for the three subsequent years of the trial, four sowing dates were used

starting on 20th September and spaced at weekly intervals. The sowing dates for each of the four years are shown in Table I.

TABLE I.
Sowing dates.

Sowing	1949-50	1950-51	1951-52	1952-53
First	20th Sept.	20th Sept.	20th Sept.	19th Sept.
Second	—	27th Sept.	27th Sept.	26th Sept.
Third	5th Oct.	4th Oct.	4th Oct.	3rd Oct.
Fourth	19th Oct.	11th Oct.	11th Oct.	9th Oct.

Planting dates.

These varied considerably from year to year. The first planting was made as soon as field conditions allowed and the others followed at approximately weekly intervals. The dates of planting are given in Table II.

TABLE II.
Planting dates.

Planting	1949-50	1950-51	1951-52	1952-53
First	8th March	5th April	19th March	16th March
Second	15th March	12th April	25th March	24th March
Third	22nd March	19th April	9th April	2nd April

General management.

Apart from sowing and planting dates the crop was handled in the same way as the commercial cauliflower crop grown on the farm. The seed was sown broadcast in cold frames and the seedlings were pricked out into rows in other cold frames for overwintering, as soon as they were large enough to handle. No special precautions were taken to exclude frost from the frames during overwintering and therefore the range of temperature to which the plants were subjected varied widely throughout the winter and from season to season. In spring, the plants were slowly hardened off in the frames before being planted out in the field. Cultivations in the field were identical with those of the commercial crop and manuring for the experiment was constant throughout the four years of the trial. Fifteen tons/acre of farmyard manure were applied to the whole area before deep ploughing in the autumn and the basal fertilizer dressing consisted of 10 cwt./acre of 7 : 6½ : 10½ mixture applied to the trial area before planting. This was followed by a top-dressing of 2 cwt./acre Nitro-chalk in May.

EXPERIMENTAL RESULTS.

Blindness and other abnormalities.

Very few blind plants were noticed in the cold frames and all those showing abnormalities at planting time were discarded. Immediately after planting, blind plants began to develop and continued to increase in numbers throughout the growing period. The amount of blindness varied considerably with the season and

the rate of development of blindness was governed largely by conditions after planting out. At least three types of abnormal growth were noted and the proportion of these varied considerably.

(a) *Blind plants.* These were by far the most numerous and were easily discernible. In place of the central growing point there was a dome-like structure with or without a whip-like elongation from its centre. The leaves were usually thicker and harder than normal and were often puckered and distorted, occasionally forming a funnel-like structure. The number of leaves produced varied from two to eleven and they were generally larger than those of the normal plant.

(b) *Plants with crested leaves.* Plants in this category produced a secondary leaf on the midrib of an otherwise normal one. This secondary leaf had a circular blade and a comparatively long centrally placed petiole. Such plants usually produced small premature curds formed by the rapid development of several lateral buds in addition to the terminal one. This type of abnormality appeared to be confined to Remme and its selections.

(c) *Premature buttons.* There were only isolated examples of this form of abnormality and it is probable that they were caused by adverse soil and climatic conditions.

Table III shows the percentage of abnormal plants for each sowing in each of the four years during which the trial was carried out.

TABLE III.
Abnormal plants, expressed as per cent. of total plants per treatment.

Sowing date	1950*	1951	1952	1953
20th Sept.	3.5	40.0	1.2	29.2
27th Sept.	—	45.5	2.5	22.9
5th Oct.	33.0	46.5	2.9	28.1
11th or 19th Oct. ..	25.1	39.5	6.7	32.9
Sig. Diff. at 1%	7.3	6.8	3.5	9.3
Sig. Diff. at 5%	5.5	5.2	2.7	6.9
Planting				
First	21.4	45.2	5.2	24.5
Second	20.4	42.0	2.5	30.5
Third	19.8	32.2	2.5	29.8
Sig. Diff. at 1%	7.3	6.3	3.2	8.0
Sig. Diff. at 5%	5.5	4.7	2.3	6.0

* Year in which the crop was harvested, and similarly throughout Tables III, IV and V.

From Table III it will be noted that there was great variability in the amount of blindness from year to year, there being little in 1952, whereas nearly half the plants were affected in 1951. While there is some indication, particularly in the first three sowings, that the amount of blindness increased slightly with delayed sowing, there appears to be no marked consistency in the results and it is obvious that factors other than actual sowing date must be the predisposing causes of blindness.

In the same way the effect of date of planting on blindness shows great variation as between seasons. Variations in the amount of blindness caused by planting date were generally small and erratic, a significant difference being recorded in 1951 only.

Yield and quality as affected by dates of sowing and planting.

The total yield from the plots also varied considerably from year to year, depending partly upon the amount of blindness present and partly on the effect of season. There was, however, a fairly constant trend in favour of the early sowings, as is shown in Table IV where the yields per plot are expressed as a percentage of that of the final sowing or planting.

TABLE IV.

Total weight of heads cut, expressed as per cent. of final sowing or planting.

Sowing date	1950	1951	1952	1953
20th Sept.	155.9	135.5	120.9	103.3
27th Sept.	—	118.9	117.8	110.9
4th Oct.	101.7	102.1	116.6	104.8
11th or 19th Oct. ..	100	100	100	100
Sig. Diff. at 1%	11.8	22.1	9.9	12.5
Sig. Diff. at 5%	8.9	13.9	7.4	9.3
Planting				
First	103.6	130.1	107.6	103.5
Second	103.0	116.0	102.5	99.9
Third	100	100	100	100
Sig. Diff. at 1%	9.9	30.3	7.9	10.6
Sig. Diff. at 5%	7.5	22.5	5.8	7.9

As regards the effect of sowing date on yield, Table IV shows that there were highly significant reductions in 1950, 1951 and 1952 as the date of sowing was delayed. A similar trend was indicated in 1953 but the differences were non-significant. In all years the average yield of October sowings was less than that of the September ones, and considerably so in the first two years of the trial.

The effect of planting date was not nearly as marked as that of sowing date, but there was a slight indication that early planting gave the best results. The trend in each year was the same but the percentage increase in yield varied widely in different seasons. In the 1951 harvest there was a 30 per cent. increase from the early planting, whereas in 1950 and 1953 the yield increase was only of the order of 3-4 per cent. Soil and weather conditions at the time of planting may have influenced these results considerably.

There was no marked interaction between sowing dates and planting dates although there was a tendency for the plants from the later sowings to do better if their planting date was delayed. This applied only to the latest sowing and there was no general indication that the age of plant at planting was a critical factor.

In Table III it is seen that in 1950 the number of blind plants varied from 3 per cent. at the first sowing to 33 per cent. at the third. There were therefore 30 per cent.

more plants at harvest from the first sowing, and this partly accounts for the 55 per cent. increase in yield shown in Table IV. When, however, this difference due to blindness was eliminated by dividing the total weight per plot by the number of heads marketed, it was found that in all years there was a gradual reduction in average weight per head from the first to the last sowing. Also there was a progressive decrease in size of head from the first sowing to the last, and this was significant in all years. Plants of the last sowing tended to produce side shoots bearing curds, sometimes just large enough to market, and this further reduced the size of the terminal head.

In general the percentage number of perfect heads was largely influenced by season but sowing date also made a contribution. As the date of sowing was delayed so the proportion of perfect heads fell. Table V gives the number of perfect heads expressed as a percentage of the total number of plants, and a general examination of the results shows that in each year there was a falling off in quality as the date of sowing became later. This was most pronounced in 1950 when there were significant differences at the 1 per cent. level between all three sowings; in 1951 a significant drop occurred only between the first and second sowings; in the last two years, only at the final sowing.

TABLE V.

Number of perfect heads, expressed as per cent. of total plants per treatment.

Sowing date	1950	1951	1952	1953
20th Sept.	50.7	19.0	32.3	25.8
27th Sept.	—	12.1	31.9	22.1
4th Oct.	31.9	13.1	30.0	20.6
11th or 19th Oct. ..	17.1	13.3	19.2	14.2
Sig. Diff. at 1%	6.2	5.8	8.6	8.0
Sig. Diff. at 5%	4.6	4.3	6.2	5.6
Planting	1950	1951	1952	1953
First	35.4	17.1	31.6	21.1
Second	34.4	13.0	25.8	19.2
Third	29.1	12.5	27.6	21.7
Sig. Diff. at 1%	6.2	5.2	7.4	7.4
Sig. Diff. at 5%	4.6	3.9	5.5	5.0

As shown in Table V there was also a slight tendency for the early plantings to give the highest quality, but this was not so regular or so marked as for the effect of sowing date. None of the differences was significant at the 1 per cent. level and in 1953 there was very little difference between the three dates of planting.

Early sowing also gave more heads of greater solidity, fewer loose curds, less riceyness, and fewer heads showing bracts, all of which are characters used in recording in the standard variety trials. Also each year there was less waste (plants failing to root when planted out, blind plants and unmarketable heads) from the first sowing. Finally the heads were marketed slightly earlier from the first than from the last sowing. Thus from consideration of Tables III, IV and V, it is obvious that the best returns are obtained from early sowing of a variety such as Remme.

Seasonal effects.

Examination of the minimum daily temperature record revealed that in years such as 1951 and 1953, when a great deal of blindness was recorded, there were spells of severe weather at the time the seedlings were young. Frost damage was shown by a whitish-grey edge to the cotyledons and, when examined under the microscope, the chloroplasts were found to be disintegrating. Fig. 1 shows the period of occurrence of these cold spells during October, November and December, together with the minimum temperatures recorded during these spells.

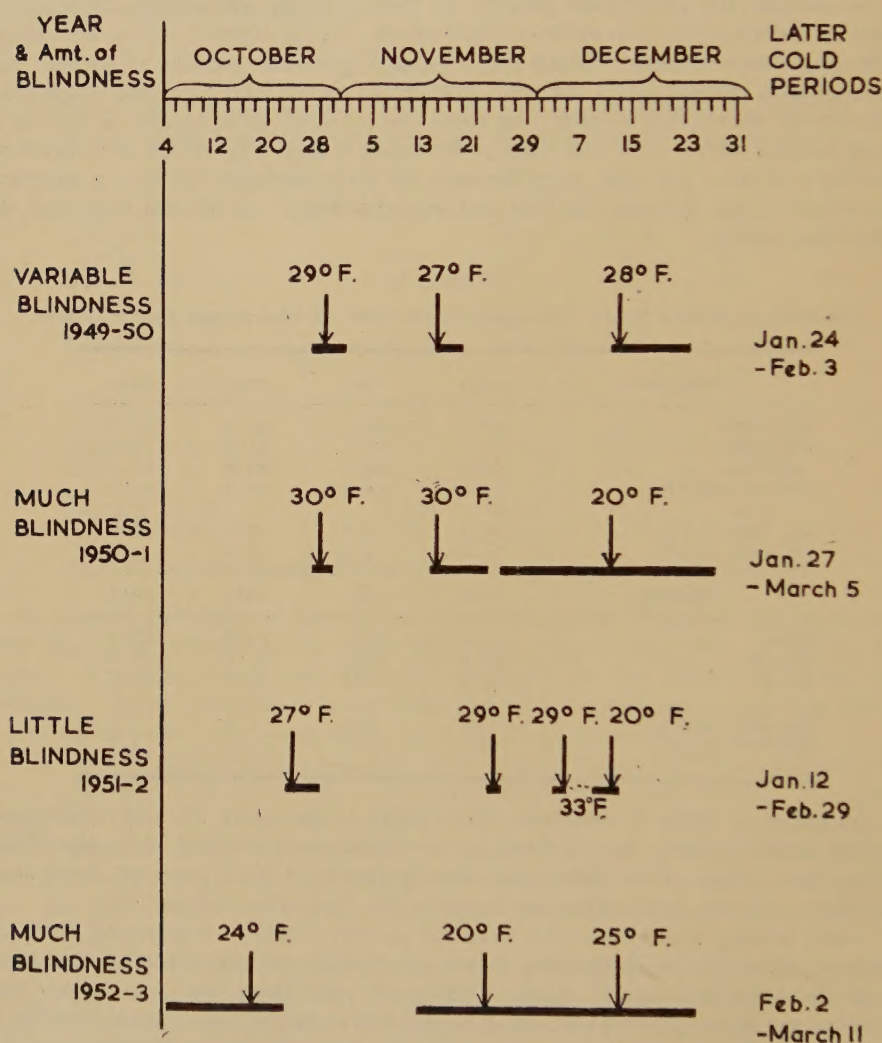


Fig. 1.

Diagram showing cold periods (32°F. or less) and minimum temperatures reached.

It is interesting to compare the information contained in Fig. 1 with that in Table III which gives the percentage of abnormal plants in each year. The latter shows that for the 1952 harvest there were very few blind plants, while Fig. 1 indicates that there were only very short spells in 1951-2 when the temperature in the frames fell below 32° F., and that the severity of frost recorded was not great while the seedlings were still small, except for the last sowing. On the other hand the greatest amount of blindness occurred in the crop harvested in 1951, when 40-46 per cent. of blind plants were recorded for September and October sowings. From the diagram it will be seen that there was in 1950-1 a prolonged spell of severe weather which started during the third week in November and continued until almost the end of December. Similarly there was a high proportion of blindness in the 1953 harvest with a correspondingly long period of frost between mid-November and mid-December in 1952. The unusual and prolonged frost in early October of 1952 would account for the unexpectedly high incidence of blindness in the crop from the first sowing of that year.

Fig. 1 also shows that in each year there were prolonged cold periods after Christmas. During these times from 10 to 13 degrees of frost were recorded. As it has already been seen that the amount of blindness varied with season, these late winter frosts do not appear to have influenced blindness. One could therefore suggest that in the early stages of growth the cauliflowers were susceptible to cold, whereas after Christmas, when the plants were larger, comparatively little damage occurred to them even though they were wilted from the frost.

DISCUSSION.

The hypothesis put forward in the foregoing paragraph—viz., that cauliflowers are more sensitive to a certain type of frost damage as seedlings than they become later on—may be used to explain not only the marked variation in numbers of abnormal plants from one season to another but also the varied effects of sowing date within the same season. In 1951-2 the one cold period of any length and severity started on 3rd December, when it would seem that the plants from the last sowing were still sufficiently young to be damaged, as in that year the only appreciable amount of blindness was in the mid-October sowing. In 1949-50, when there was a marked amount of blindness in the two October sowings, there was a cold period in mid-November, followed by a longer one which started on 12th December and continued for twelve days. At this latter time the plants in the last sowing were approximately of the same age as those experiencing a similar cold spell in 1951-2, as they were sown 8 days later. In 1950-1 and 1952-3 prolonged cold periods began at about mid-November and all the sowings in both years gave a high percentage of abnormal plants. This problem will need further examination, and it will be necessary to design an experiment in which seedlings at different stages of growth can be submitted to varying degrees of frost severity.

Although planting date did not apparently have a direct effect, it appears to have modified that of sowing date. For example, in the first planting of each year, the first sowing gave the least blindness and the fourth the most, which was also shown by Wiebosch and his co-workers (*loc. cit.*). But in the third planting there were many fewer blind plants among those sown in mid-October (the fourth) than in early October (the third), so much so that the total for this planting was less than

that for the first and second (see Table III). It was observed that plants from the mid-October sowing re-rooted more readily than those of other sowings and, by the time the third planting took place, field conditions were more likely to encourage the growing out of these roots. This may have been one of the reasons for the reduced amount of blindness.

Another factor masking the effect of sowing date in mid-October sowings may be the "recovery" of blind plants which was observed when frequent counts of blind plants and the plotting of their exact position on charts were made. It was found that some plants which had been originally noted as being blind produced a curd suitable for marketing. These plants had developed a lateral bud in place of the terminal one, and in some years had produced marketable heads in time to be cut with the rest of the crop. Wherever such recovery had occurred it was noted that adventitious roots developed from a leaf scar immediately below the developing bud. The greatest degree of recovery occurred in 1951 and 1953, which were years of severe blindness, and a large number of recovered plants were noted only in the mid-October sowing in 1950. This power of producing adventitious roots and heads from lateral buds was confined almost entirely to the plants obtained from October sowings and in 1951, the year of maximum amount of recovery, there were as many as 9.4 per cent. of the total plants which had so recovered.

It would appear, therefore, that the proportion of blind plants occurring in any crop may be influenced by several factors, probably the most important being the temperature which the seedlings experience when young. It has been shown that low temperature when the seedling is at a certain stage of development is likely to produce blindness. Usually, in the neighbourhood of Kirton, the October sowings have reached this susceptible stage when severe frosts occur before Christmas, whereas the earlier sowings are large enough to escape most of the damage. This would indicate that, in areas susceptible to late autumn frosts, adequate protection against severe weather should be provided for the young seedlings.

The date of sowing the seed appears to be less important for blindness but it greatly influences the total weight of crop and the quality of the heads produced. Planting date influences yield and quality to a lesser extent and appears to have little effect on blindness except in so far as blind plants from a late sowing, if planted out late, appear to have a greater chance of re-rooting and producing a saleable curd from a lateral bud.

SUMMARY.

1. The effects of different sowing and planting dates on blindness, yield and quality of early summer cauliflower were studied.
2. There was great variation in the amount of blindness from one year to another; within limits, sowing date also influenced the amount of blindness.
3. Planting date had little direct effect on blindness, but late planting encouraged the October sowings to re-root more readily, consequently reducing blindness.
4. Early sowing increased weight of crop (trimmed heads) per plot, size of head, solidity of curd, the number of perfectly shaped heads, and other quality characters.

5. Though planting date was less effective than sowing date, early planting tended to give the greatest weight per plot, but had little effect on quality characters.
6. Frost periods, particularly in late autumn, were shown to affect the subsequent amount of blindness ; the relationship between these cold periods and age of plant, as influenced by sowing date, is discussed. Severe cold after Christmas, when the plants were older, had no effect.
7. Factors which may ameliorate the effect of late sowing date are discussed.

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THE EFFECT OF ORCHARD FACTORS ON THE CHEMICAL COMPOSITION OF APPLES

I. SOME EFFECTS OF MANURIAL TREATMENT AND OF GRASS

By B. G. WILKINSON

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THE extent to which orchard factors affect the chemical composition, quality and storage life of fruit is being studied jointly by the Ditton Laboratory and the East Malling Research Station. The results to be considered below are concerned with chemical composition only and refer entirely to Cox's Orange Pippin apples grown under varying conditions. The storage results will be presented separately.

Of the figures obtained, the more important are for the 1954 and 1955 crops from 64 trees of an East Malling manurial trial. These trees (which are on rootstock M. XII) are set out in randomized blocks for a study of the effects of nitrogen, phosphorus and potassium, and of clean cultivation against grass cover. The original layout of this trial has been described by Hoblyn (1941). It was modified in 1953 by sowing half the plots to a grass sward mixture. There are now eight basic manurial treatments consisting of NPK, NP, NK, PK, N, P, K, and O and each treatment is applied to four trees in clean cultivation and to four in grass. Where the treatment is applied to a plot with grass cover the suffix S (for sward) has been added, and so the eight grass treatments are represented as NPKS, NPS, NKS, PKS, NS, PS, KS, and S alone.

The amounts of fertilizer per acre per year signified by the letters N, P and K have been as follows :

N.	1931-40, 1½ cwt. sulphate of ammonia.
	1941-52, 3 cwt. " "
	1952-55, 6 cwt. " "
P.	1931-55, 5 cwt. superphosphate.
K.	1931-55, 2 cwt. sulphate of potash.
O.	No fertilizer.

The basic multiple treatments are obtained by adding the amounts for N or P or K as necessary. In addition, because of a potash deficiency, the whole trial had a supplementary dressing of 2 cwt. per acre per year of sulphate of potash from 1937 to 1953 inclusive. The grassing-down took place in April 1953.

Details of the soil of this orchard are given by Furneaux (1954). This particular plot is in Churchfields East and is described under " Malling " and " Barming Series ".

Analyses have also been made of Cox's Orange Pippin apples selected from bulk storage samples from various commercial and other orchards in East Anglia, Essex, Kent and Sussex. These apples serve to indicate the range of storage behaviour and chemical composition to be expected within the variety, even though their previous history is not as well defined as the experimentally controlled East Malling samples.

Sampling for analysis.

Each sample of apples consisted of 25 fruits selected at random from bulk samples. The stalks and seeds were removed from the halved apples, which were frozen at -20°C . for at least 24 hours. Each sample was then ground at -10°C . and the resulting powder was stored at -20°C ., in tins with close-fitting lids, until required.

In 1954, apples from each tree were analysed separately, but in 1955 the 25 apples from each of the four trees comprising a treatment were mixed together and ground as one sample. The crop from the KS treatment was so small in 1955 that it was not possible to obtain 25 apples from each tree. A composite sample of 25 was therefore selected from amongst the four trees.

Methods of analysis.

Apart from acidity, which was measured in water extracts of the ground tissue, all the estimations involved an initial ashing. In 1954, samples of approximately 15 gm. were oxidized with nitric and perchloric acids, and the residue was taken up in nitric acid and made up to volume. Later it was found that a modification of the method of Middleton and Stuckey (1954) was suitable for apple tissue. This method uses nitric acid alone and it was found that 100 gm. samples could be handled conveniently. The residue was evaporated to dryness with hydrochloric acid, taken up again in hydrochloric acid, and finally filtered and made up to volume and stored in borosilicate bottles until required.

The nitric acid method of ashing, apart from being more convenient and less hazardous, gave a higher recovery of phosphorus, as claimed by Milton, Hoskins and Jackman (1944). Potassium figures were identical by both methods.

The following chemical analyses were made on the 1954 crop :

Potassium. A known volume of the ash solution was diluted as required and the potassium estimated directly by flame photometer.

Calcium. After removal of interfering groups, this was measured on the flame photometer. Nitric acid was removed and the ash taken up in hydrochloric acid. The solution was passed through an anion exchange column (Amberlite I.R. 4B (Cl)) and the hydrochloric acid evaporated off. Calcium was then precipitated from aqueous solution by ammonium oxalate and oxalic acid at pH 5. The precipitate was redissolved in nitric acid and the solution diluted to less than decinormal before spraying through the flame photometer.

Magnesium. The magnesium in a known volume of ash solution was determined colorimetrically by the Titan Yellow method, using a Hilger "Spekker" (Sandell, 1944).

Titrateable acid. A weighed amount of the ground tissue was mixed with water in a Waring blender and the free acid determined by potentiometric titration against decinormal sodium hydroxide.

The following additional elements were estimated in 1955 :

Phosphorus. A method (Dippel, Bricker and Furman, 1954) based on the quantitative depression by phosphorus of the flame photometer reading of a standard calcium solution was used.

Sodium was measured directly by flame photometer.

Manganese was estimated colorimetrically by the periodate method, as described in Sandell (1944).

Sulphur was estimated by the nephelometric method of Obermer and Milton (1932).

RESULTS.

East Malling fruit.

The results for the two years are collected in Tables I and II. In Table I (1954 crop) only the means for the treatments have been given, not the analyses for the individual trees. Sometimes there was considerable variation from tree to tree and it is not known to what extent this is attributable to sampling errors. Even so, useful general conclusions can be drawn from the average figures per treatment, especially when the effects are consistent for similar treatments and from season to season. The discussion will be confined to these mean values. For the sake of completeness figures for "Total Nitrogen" on the same samples, as given by Hulme (1956*b*), have been included in the Tables.

In this paper the direct effect of treatment and of season on composition will be considered; the interrelationship between some of the constituents will be considered in a later paper. Before examining the figures it should be pointed out that there was a big difference in the fruit of the two seasons. The 1954 crop was heavy whereas in 1955, though the trees of some treatments (for instance N, PK, and O) cropped well, the crop on the whole was very light and it was only just possible to obtain a total of 25 sound fruits from the four trees of KS. Again, the average weight of individual apples in 1955 was abnormally high and, for the apples used for analysis, was 120.1 gm. as against 86.2 gm. for those used in 1954. For comparison, the average weight of the apples of the six treatments from this orchard analysed by Hulme in 1953 was 98.3 gm. (Hulme, 1956*a*).

The following conclusions have been drawn from the results for the manurial trial:

Phosphorus (Table II). Firstly, the addition of phosphorus to the soil had a negligible effect on the phosphorus content of the apples (average for all treatments containing P, 15.9 mg.; for all treatments without P, 15.7 mg.). Secondly, grass increased the phosphorus content considerably (average for all grass treatments, 17.9 mg.; for all clean cultivated treatments, 13.7 mg.). The grass treatment always showed a higher value than the corresponding clean cultivation. Thirdly, the apples from the four basic treatments which included nitrogen were lower in phosphorus than those from the four basic treatments without nitrogen.

Potassium (Tables I and II). There was a direct effect of potash manuring on potassium content in both seasons. In all 16 samples of apples from potash treatments the potassium figures were higher than in those without potash (average for all potash treated plots in 1954, 144 mg.; for all plots without potash, 128 mg.; corresponding averages for 1955, 177 and 153 mg.). The effect of grass, namely a tendency to increase potassium content in the absence of applied nitrogen but not where nitrogen had been added, was also consistent in the two seasons. As between the two seasons, the average potassium content was much higher in 1955 (165 mg. as against 134 mg. in 1954), and the grass treatments were, on the whole, higher relative to cultivation than in the previous season.

TABLE I.

*East Malling manurial trial, 1954. Composition of apples from the 16 treatments.
Each value is the average of determinations on 4 trees.*

Treatment	Total N*	K	Ca	Mg	Titratable acid as malic (% F.W.)	Weight (gm.) of 25 apples
NPK	—	165	6.8	5.4	0.77	2,329
NPKS	—	140	7.1	4.9	0.75	2,146
NP	—	136	6.8	4.4	0.71	2,371
NPS	—	124	7.0	5.0	0.72	2,144
NK	62.4	152	6.5	5.0	0.76	2,205
NKS	47.2	136	6.9	5.1	0.74	2,172
PK	—	142	6.9	4.7	0.74	2,182
PKS	—	144	7.9	5.5	0.79	2,060
N	63.7	123	6.2	4.3	0.69	2,313
NS	46.1	126	7.3	4.6	0.70	2,198
P	—	103	7.7	3.6	0.64	1,981
PS	—	134	8.2	5.4	0.73	2,006
K	56.8	139	7.1	4.8	0.72	2,226
KS	34.7	135	7.8	5.3	0.76	1,887
O	59.8	114	6.3	4.4	0.66	2,202
S	39.6	130	7.9	5.2	0.75	2,061
S.E. of Means ..	—	4.5	0.33	0.16	0.013	94

* All chemical analyses in Tables I and II are given in terms of mg./100 gm. fresh weight.

TABLE II.

East Malling manurial trial, 1955. Composition of apples from the 16 treatments.

Treat- ment	Total N	P	K	Ca	Mg	Na	Mn	S	Titratable acid as malic (% F.W.)	Weight (gm.) of 25 apples
NPK ..	68.8	12.0	193	4.7	6.4	2.5	0.105	6.6	0.93	3,575
NPKS ..	55.4	17.1	177	4.4	6.9	3.0	0.073	6.6	0.93	2,937
NP ..	67.6	13.4	166	4.1	5.1	2.3	0.103	6.2	0.85	3,598
NPS ..	54.8	16.8	166	4.7	6.1	3.0	0.076	6.2	0.91	2,764
NK ..	63.8	13.1	182	4.2	6.5	2.8	0.088	6.4	0.93	3,366
NKS ..	55.8	16.8	173	4.9	6.0	3.3	0.062	5.9	0.91	2,884
PK ..	63.8	15.2	161	4.4	6.0	2.5	0.044	6.8	0.85	3,134
PKS ..	53.8	19.0	173	4.5	6.8	2.8	0.041	6.3	0.89	2,653
N ..	68.8	12.5	155	4.7	5.4	2.4	0.095	6.5	0.82	2,985
NS ..	52.6	15.5	152	4.7	5.6	2.5	0.061	6.0	0.85	2,836
P ..	59.6	14.7	127	4.2	5.3	2.4	0.043	5.6	0.77	2,885
PS ..	55.8	19.0	164	4.5	6.1	3.1	0.047	5.6	0.89	2,678
K ..	61.4	14.7	170	4.4	6.1	2.7	0.046	6.1	0.88	3,258
KS ..	51.2	19.9	184	4.8	6.4	3.3	0.046	5.4	0.95	2,924
O ..	61.8	14.4	129	5.1	5.3	2.5	0.045	6.8	0.75	2,694
S ..	57.8	19.0	164	5.1	6.4	2.8	0.041	5.8	0.86	2,886

Statistical analysis of the results for the 64 individual trees in 1954 showed that the effect of applied potash was significant at the 0.1 per cent. level, as were also the differences between grass treatments in the presence and absence of nitrogen.

Magnesium (Tables I and II). The magnesium levels were all considerably higher in 1955 than in 1954 (average for all treatments, 6.0 mg. in 1955 ; 4.8 mg. in 1954). Moreover, as with potassium, grass caused a greater increase in magnesium content on those plots which had not received nitrogen. In general, and in both seasons, the trees receiving potash showed a higher level of magnesium in the apple than did corresponding trees not receiving potash.

Statistical analysis of the results for the 64 individual trees in 1954 showed that the effects of potash and of grass were significant at the 0.1 per cent. level, as were also the differences between grass treatments in the presence and absence of nitrogen.

Acid (Tables I and II). The general level of the free acid at the picking date was higher in 1955 than in 1954, the respective averages being 0.87 and 0.73 per cent. fresh weight. On the whole, potash increased acid, as did grass. The four treatments in which nitrogen was omitted all showed a marked increase in acid when grass replaced cultivation. A further feature was that in both seasons NPKS and NKS were the only grass treatments which did not give higher acid than the corresponding cultivation treatment.

Statistical analysis of the results for the 64 individual trees in 1954 showed that the effects of potash and of grass were significant at the 0.1 per cent. level as were also the differences between grass treatments in the presence and absence of nitrogen.

Calcium (Tables I and II). There was no obvious effect of treatment on calcium content, although there was a possible increase due to grass, especially in 1954. The outstanding difference between the two seasons was that in 1955 the calcium content per unit weight was very much lower (average in 1955, 4.6 mg. ; 7.2 mg. in 1954).

Sodium (Table II). The sodium content was consistently higher in grass plots than in corresponding cultivated plots, the overall averages being 3.0 and 2.5 mg. respectively.

Manganese (Table II). The apples with the highest manganese content were those which had received a nitrogen dressing. Where grass was present in addition to nitrogen the manganese figures were lowered. In the absence of nitrogen there was no apparent effect of grass.

Sulphur (Table II). There was some indication that grass reduced sulphur content.

Nitrogen. "Total nitrogen", "Protein nitrogen", and "Soluble nitrogen" contents for the apples from some of the plots have been given by Hulme (1956b). His estimations were for N and NS, K and KS, NK and NKS, and O and S in 1954, and for all treatments in 1955. The "Total nitrogen" figures have been included in Tables I to IV.

Commercial fruit.

A detailed analysis of the figures (Tables III and IV) for these apples has not been attempted, because not only is much less known about their culture and sampling, but differences in soil and climate may be sufficiently great to obscure effects of manurial treatment. However, the figures show certain trends which support the conclusions drawn from the East Malling manurial trial :

TABLE III.

Composition of apples from commercial orchards, 1954.

Orchard code no.	Total N*	K	Ca	Mg	Titrateable acid as malic (%F.W.)	Weight (gm.) of 25 apples
K2	49.8	133	5.3	5.4	0.85	1,782
K3	40.6	137	7.4	4.2	0.86	1,806
FPN	58.8	129	8.1	5.3	0.85	1,712
FPU	81.4	166	5.9	5.1	0.91	2,306
M	51.8	132	5.5	3.9	0.80	2,463
R4	52.6	121	5.9	4.3	0.76	2,612
R5	60.4	110	6.5	4.0	0.64	2,586
CBI	57.6	146	6.4	5.7	0.89	2,654
CBNI	51.6	136	6.8	4.8	0.78	2,056
RCF	55.8	122	6.8	3.7	0.74	2,351
RG	69.8	141	6.9	4.2	0.84	2,496
RP	71.2	119	7.5	3.7	0.74	1,856
D	62.4	113	9.0	5.2	0.80	1,937
WD2	71.6	140	8.0	5.4	0.92	2,318

* All chemical analyses in Tables III and IV are given in terms of mg./100 gm. fresh weight.

TABLE IV.

Composition of apples from commercial orchards, 1955.

Orchard code no.	Total N	P	K	Ca	Mg	Na	Mn	S	Titrateable acid as malic (%F.W.)	Weight (gm.) of 25 apples
K2 ..	54.8	13.8	170	5.9	6.3	1.7	0.063	5.7	0.98	1,945
K3 ..	45.8	15.6	186	5.3	6.4	2.1	0.044	5.0	1.06	2,205
FPN ..	64.8	13.1	173	5.5	6.5	2.5	0.086	6.4	0.85	3,052
FPU ..	66.6	15.2	182	4.3	6.6	2.3	0.063	5.7	0.88	2,887
M ..	60.4	11.4	113	4.5	4.5	2.3	0.052	5.3	0.87	3,189
R4 ..	73.0	12.8	113	5.5	5.1	1.8	0.050	5.6	0.88	2,643
R5 ..	65.2	12.5	105	7.5	4.9	1.8	0.055	5.9	0.80	2,366
EM ..	61.6	14.4	148	4.5	5.6	1.7	0.054	6.1	0.85	3,390
H ..	39.6	16.8	175	5.9	6.0	2.5	0.052	4.6	1.17	3,014

1. The acidity figures were almost all higher in the 1955 season.
2. Comparison of the seven orchards for which data for both seasons are available shows that the potassium figures were on balance higher in 1955. Four were substantially higher and only one was much lower.
3. The 1955 calcium figures were, on the whole, lower in a season when fruit tended to be larger.
4. Especially in 1955, high magnesium figures were associated with high potassium figures.

In addition, the commercial fruit gave further indications of the range in composition which can be found within a variety. The extreme values are collected in Table V, which shows the big differences in composition which have been observed. These figures are for composite samples of 25 apples, so that the range in individual apples would be even greater. The Table also includes the East Malling fruit and it will be seen that, even within the limits of a single orchard, the manurial programme and season can have a large effect on the chemical composition of the apples.

TABLE V.

Observed variation in composition (mg./100 gm. fresh weight) over two seasons.

	Commercial fruit (from Tables III and IV)		East Malling fruit (from Tables I and II)	
	Highest value	Lowest value	Highest value	Lowest value
Phosphorus	16·8	11·4	19·9	12·0
Potassium	186	105	193	88
Magnesium	6·6	3·7	6·9	3·1
Calcium	9·0	4·3	9·5	4·1
Sodium	2·5	1·7	3·3	2·3
Manganese	0·086	0·044	0·105	0·041
Sulphur	6·4	4·6	6·8	5·4
Total nitrogen (Hulme, 1956b)	81·4	39·6	68·8	30·0
Titrateable acid as malic (% F.W.)	1·17	0·74	0·95	0·61

DISCUSSION.

The discussion, which will be confined to the results for East Malling fruit, can be divided conveniently into four sections—the effects of fertilizers, of grass, of season, and of crop size. Of these, the first two are of main interest because they can be controlled. Climate and crop size can be considered as modifying influences.

Effects of fertilizers. The outstanding feature is that, whereas added nitrogen increased nitrogen content, and added potash increased potassium content, added phosphorus had a negligible effect on phosphorus content. In fact, adding superphosphate does not appear to have made any difference at all to the composition of the fruit in respect of any of the constituents examined. Nor was the average fruit weight affected.

On the other hand, as judged by the weights of the analytical samples, nitrogen application increased fruit size, the average weight of the 25 apples from plots

receiving nitrogen being about 8 per cent. higher than that of fruit without nitrogen in both 1954 and 1955. This fact may be a clue to the difference in phosphorus content between apples from the four basic treatments containing nitrogen and apples from the four treatments without nitrogen. Or it may be that applied nitrogen reduced the availability of phosphorus in the soil.

The large effect of applied nitrogen on the manganese content may be due to the more acid conditions which would be expected to follow the application of ammonium sulphate to the soil; it is well known that manganese uptake is greatly influenced by soil pH. It is significant, too, that the manganese content was lower on those N plots where available nitrogen had been lowered by competition from grass.

Effects of grass. It should be emphasized that the crops analysed were those of the first two full seasons after grassing down and, since grass may not show its full effects for several years, the long-term effects on fruit composition may be somewhat different from those reported here. The immediate effects to be expected would be those resulting from a drier soil, absence of disturbance of the surface layers, and competition for nutrients.

Of the observed chemical effects, apart from that on nitrogen content (Hulme, 1956b), the most obvious is that apples from grass plots were much richer in phosphorus, a result previously reported for trees from Long Ashton (Wallace, 1953). The difference was considerable, the average phosphorus content of apples from grass plots being 17.9 mg./100 gm. fresh weight as against 13.7 mg. for cultivated plots, the increase due to grass being 30 per cent. Also the magnitude of the effect of grass on phosphorus content was independent of applied superphosphate.

Effects of season. Table VI summarizes some of the weather data for the first nine months of 1954 and 1955 at East Malling. The total rainfall for the first three

TABLE VI.
Weather data at East Malling in 1954 and 1955.

Quarter	Mean temperature		Rainfall (in.)			Sunshine (hours)		
	1954	1955	35 yr. av.	1954	1955	25 yr. av.	1954	1955
1	39	37	5.82	6.29	6.36	238	208	249
2	51	52	5.36	4.61	5.84	574	495	584
3	58	61	6.36	6.94	5.27	549	447	587

quarters of each year was almost the same, although the third quarter of 1955 was drier than average. The biggest difference between the two years was in the amount of sunshine, each quarter of 1954 being much below average and each quarter of 1955 being above.

For these two particular years there is another effect of season to be considered. Not only was 1955 a sunnier season, but the reduced crop resulted in larger individual apples. As previously mentioned, the average fruit weight in 1955 (based on 25 apple samples) was 120.1 gm. as compared with 86.2 gm. in 1954. The 1955 apples had higher nitrogen, higher potassium and higher magnesium, but much lower calcium, and the low calcium figures may be due to increased fruit size.

Martin and Lewis (1952) reported that the difference between the large fruits of light crops and the smaller fruits of heavy crops was largely one of cell size, the larger apples having larger cells. On this reasoning, and assuming the calcium to be mainly in the cell walls, one would expect the smaller apples of 1954 to have a greater amount of calcium per unit weight because they would have a greater proportion of cell wall.

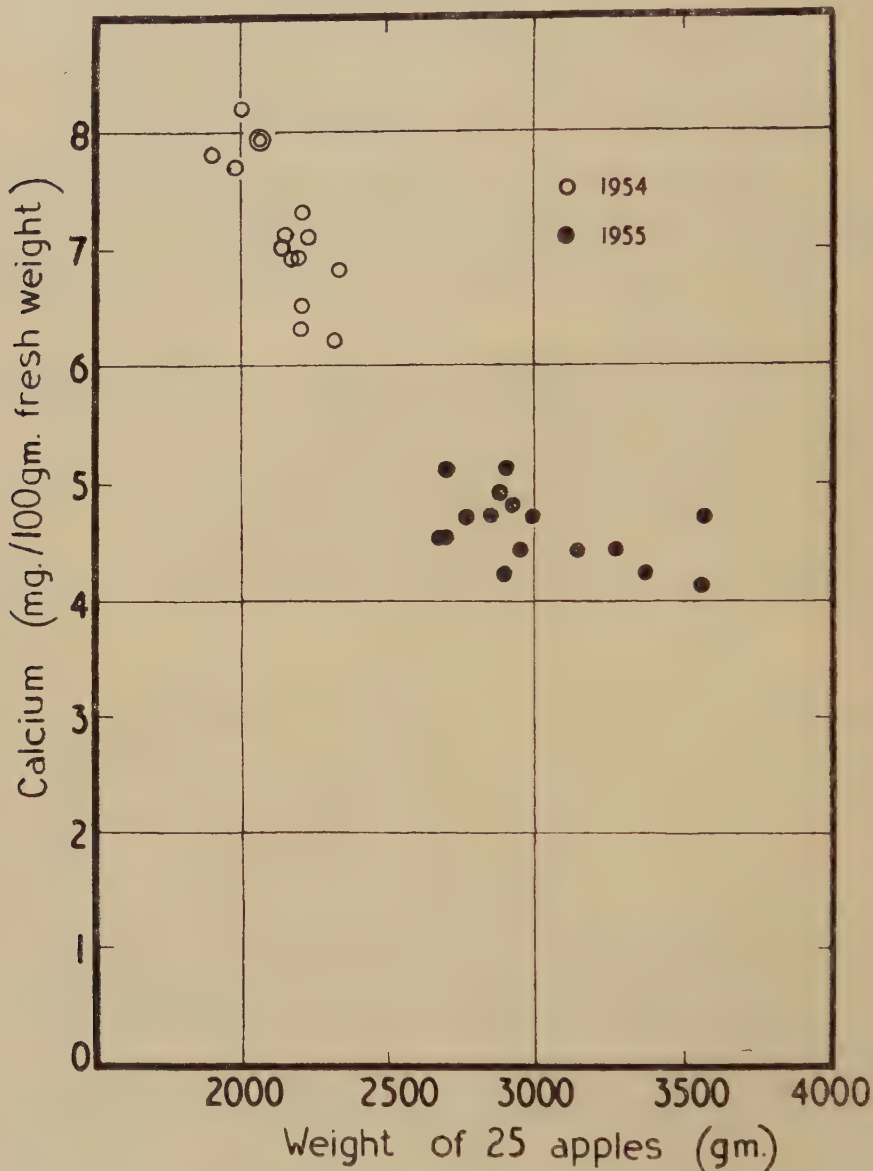


FIG. 1.
Calcium content and fruit weight of apples.

In Fig. 1 the average calcium figures per treatment are plotted against the weight of 25 apples (for the two seasons) and it will be seen that, in 1954, apples from treatments favouring higher fruit weight tended to have less calcium per unit weight than did smaller apples; in 1955 the effect was less obvious.

There was no obvious relationship between potassium content and fruit weight and it is not known to what extent the higher potassium figures in 1955 were due to differences in the weather. It may be that the sunnier season, combined with adequate rainfall, was the indirect cause of high potassium content by favouring high acid production. The probable interdependence of potassium and acid has been stressed by Tomkins (1954).

Phosphorus, too, is believed to have been much higher in 1955. Although the figures for 1954 have not been presented because of suspected losses during ashing, they were on the average 40 per cent. lower than in 1955, a difference which is almost certainly more than could be accounted for by ashing losses.

Magnesium also was higher in 1955 (an average of 6.0 mg./100 gm. fresh weight as against 4.8 mg. in 1954) and tended to follow potassium. This is contrary to what is usually found in the composition of leaves and suggests the need for a critical comparison of leaf and fruit analysis data.

Effect of crop size. For the two seasons under review the number of apples produced per tree had little effect on the relative amounts of the substances measured. In 1955 it was only just possible to obtain 25 apples from the combined crops of the four KS trees; yet the overall figures for KS are consistent with those of KS for the previous season when the total crop was very much heavier and the yield from the KS trees was normal. Again, O and N, which had comparatively good crops in 1955, are not anomalous in comparison with other treatments and with the previous season. For the present discussion it is felt that crop size can reasonably be disregarded.

Finally, it should be pointed out that the fruit from all the East Malling trees was picked at the same time, and that there may have been slight differences in the maturity of the fruit from the different treatments. It is not considered that this could have affected any of the conclusions drawn as to the effects of treatment on the composition of the fruit.

SUMMARY.

1. Cox's Orange Pippin apples from an NPK manurial trial have been analysed and the results for two seasons have been given.
2. Potash application increased the potassium content of the apples by an average of 12 per cent. in 1954 and 15 per cent. in 1955, but application of superphosphate had no effect on any of the constituents measured.
3. Grass cover increased phosphorus concentration in the apple by about 30 per cent. and also increased sodium in all treatments. Where nitrogen had not been applied, grass cover also substantially increased potassium and magnesium contents and titratable acidity.
4. In the sunnier 1955 season, titratable acidity and potassium and magnesium concentrations were all higher, but the larger apples of an abnormally small crop had an average of only 4.6 mg. of calcium per 100 gm. fresh weight as against 7.2 mg. in the previous season.

5. The figures given, and those for commercial samples, indicate that, between orchards and between manurial treatments, there may be a range of at least two-fold in the concentrations of some of the major mineral elements ; potassium has varied from 88 to 193 mg. per 100 gm. fresh weight, magnesium from 3.1 to 6.9, calcium from 4.1 to 9.5, and phosphorus from 11.4 to 19.9.

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The data for 1954 were analysed statistically by Mr. G. H. Freeman of the East Malling Research Station.

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A METHOD OF GROWING APPLE TREES BY SPRAYING THEIR ROOTS WITH NUTRIENT SOLUTION

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I. GENERAL DESCRIPTION

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THE growing of apple trees in water culture has proved difficult in the past. The roots have tended to become covered with a slime of fungi and bacteria and have then died. Barker (1921) avoided this difficulty by spraying the roots with a nutrient solution instead of immersing them in it. The method to be described here makes use of this idea. Vyvyan and Trowell (1953) have described a "mist" method based on the same principle. This method is being carried on and modified by Maggs and Trowell. Bird and Ruck (1956) have made a systematic study of some of the factors involved in growing apple trees in water culture and Bolas and Ruck (1956) have obtained promising results on a larger scale during the summer of 1955. The three methods have been developed side by side with much interchange of ideas and experience. It seems likely that each may have its own field of utility.

In the spray method to be described here, the plant was suspended with its roots in mid-air, as in Vyvyan and Trowell's mist method, and was thus dependent for its moisture on the spray or mist. Interruption of moisture supply for twenty minutes on a hot day has resulted in the death of all fine roots and a consequent serious check to growth of the plant as a whole. The success of these two methods is, therefore, dependent on a continuous supply of nutrient solution to the roots, and the difficulty of ensuring this still constitutes a serious practical disadvantage in their use as compared with water culture.

The main purpose of the method was to grow small apple trees under controlled conditions of mineral nutrition, including deficiencies of the trace elements. As in the method described by Vyvyan and Trowell (1953) the trees were grown in the open so as to avoid the expense and the unnatural conditions of a glasshouse. The possibility that trace elements might be supplied to the "deficient" plants in appreciable quantities by wind-borne dust had to be faced. For this reason the nutrient solution was sprayed once only on to the roots and was then allowed to run to waste. It was hoped that, as a result of this procedure, any dust reaching the roots would not remain long in contact with them but would be washed off by nutrient solution, which could be protected from dust until the last moment before spraying. A greater degree of economy in the rate at which the nutrient solution was sprayed had, therefore, to be exercised in the present method than was called for in the mist method. Although good growth was made by the plants in the first season (1951), this was in spite of a number of "droughts"; with improvements in the apparatus, growth was better in 1953 and 1954, and better still in 1955. What

follows is a description of the apparatus with improvements incorporated up to the end of the 1955 season.

A diagrammatic representation of the apparatus is shown in Fig. 1, consisting of three panels each drawn to a different scale. The upper part shows a plan of the apparatus as a whole, and the lower part the corresponding elevation. A general view is given in Fig. 2. A brief description will be followed by more accurate ones of the main parts by the workers chiefly responsible and by preliminary data on growth and performance of the plants and on their mineral composition.

Water from the mains was passed through a filter into tanks 2 and 5 (Fig. 1) where it was treated for removal of hardness and of some mineral constituents; thence in succession into tank 17 where it was adjusted to pH 5.5, into eight mixing tanks 21 where the appropriate concentrated nutrient solutions were added, then into the corresponding reservoir tanks 29. From each of the latter the nutrient solution was siphoned to a float-chamber 31, whence it was carried to four small feed reservoirs 41 (of which there were thirty-two altogether, two for each tree-container in the outfit). Definite volumes were pipetted in an automatic manner from 41 into receptacle 42, thence through the lid 65 of culture apparatus 63 to a rotating disc 67 which flung liquid as a fine spray on to the roots of sixteen small apple trees arranged in a circle round it.

Each rotating disc was driven by an electric motor rated at 25 volts D.C.; but to obtain long life it was run at 5 volts only. This gave sufficient speed to throw the water droplets with a fall of 1 in 30 from the horizontal. For safety the current from the mains was transformed down to 5 volts before entering the experimental area. The current from the transformer was fed through a full-wave rectifier and through a simple smoothing circuit to the motors. In spite of fluctuations in mains voltage this circuit gave a sufficiently constant motor speed to produce a satisfactory spray. For the motor actuating the dispensing unit, however, a more constant voltage was found necessary. This was obtained by the use of a constant voltage transformer.

II. WATER PURIFICATION AND PREPARATION OF NUTRIENT SOLUTIONS

(W. A. Roach)

Water filtration.

The purpose of filter 6 (Fig. 1) was to free the water from a gelatinous substance which contained iron. It was made up of standard materials obtained from water supply engineers and is shown in detailed section in Fig. 3. The inner tube 14 was perforated with numerous holes 9. Round this was wound a spiral of plastic-covered cord 10 to act as a spacer and over this nylon fabric 11, then absorbent cotton wool 12 and finally cellulose wadding 13, the whole being held in position by string. The coverings were tied tightly at each end so that the water had to pass through the full thickness of the wrappings. After passing through this filter a 7 ft. depth of the water usually appeared crystal clear. After use for a month or so the filter bed became partially clogged and the flow of water was impeded. When this happened the filter was dismantled and set up afresh.

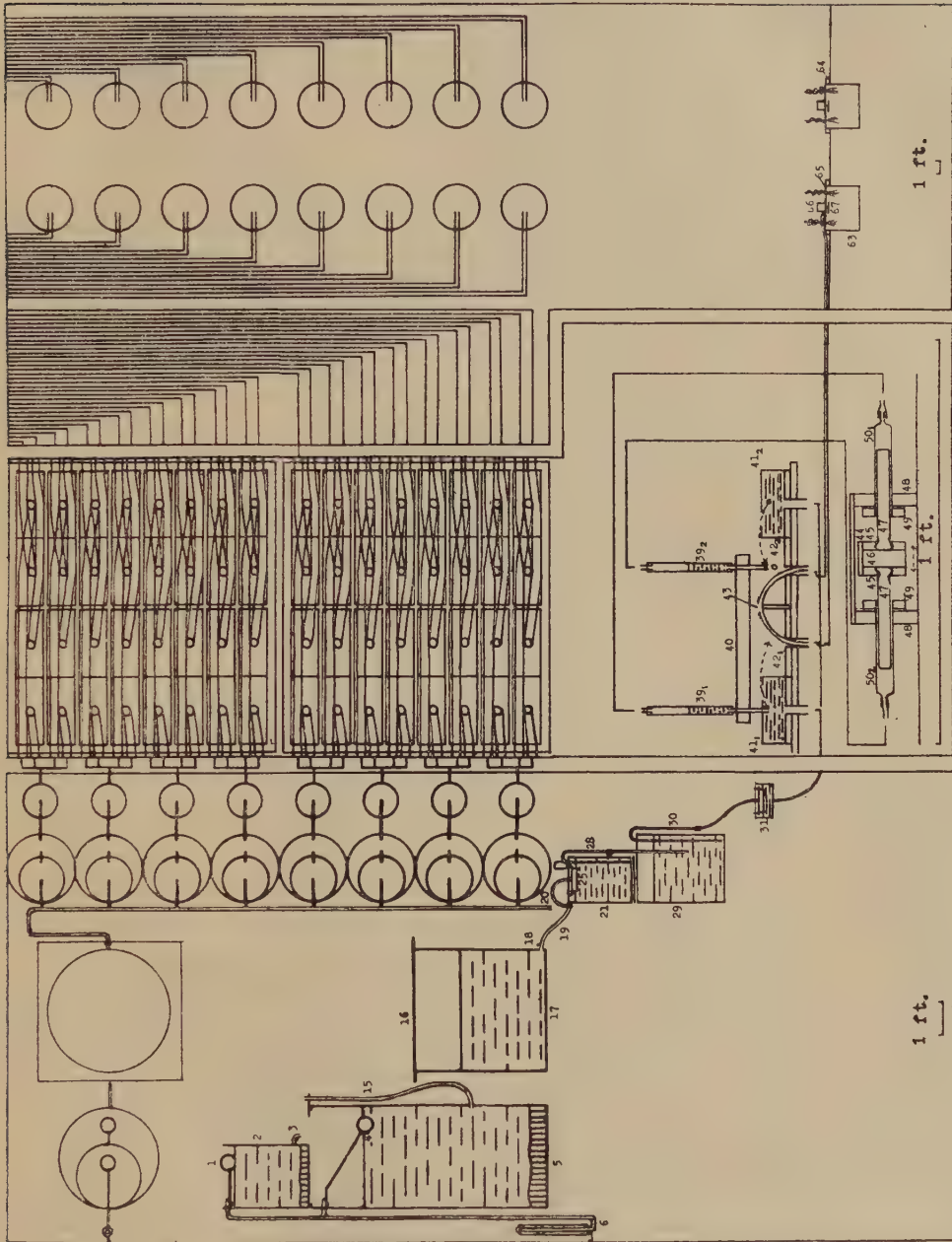


FIG. 1.
Spray culture apparatus.—plan (above) and section (below).

Water purification.

The filtered water was first passed along galvanized iron tubing into iron tanks 2 and 5 (Figs. 1 and 2) of approximately 40 and 270 gallons capacity respectively. These were given three coatings of bitumen paint on their inner surfaces. Tank 2 was provided with a tap 3, about 4 in. up the side and an inlet, controlled by a ball valve 1, near the top. Tank 5 was also provided with an inlet, controlled with a ball valve 4, about 6 in. from the top, and an outlet, connected 2 ft. up the side with PVC hose 15, for drawing off the purified water. The sludge accumulating in the tank was periodically drawn off by means of a tap at the bottom.

The usual procedure was to slake 300 gm. of quicklime with a small volume of water to form a slurry. This was added to tank 2 (already filled with water) and stirred thoroughly. The water was thus saturated with calcium hydroxide, the excess of which settled to the bottom of the tank on standing. 115 gm. ammonium dihydrogen phosphate were added in solution to tank 5 and the liquid mixed by blowing air through it. The calcium hydroxide solution in tank 2 was now run into tank 5, the contents were mixed again and the precipitate allowed to settle overnight. Usually the supernatant liquid was crystal clear by the morning, but occasionally it was opalescent. No explanation for this opalescence was found nor any way of avoiding it with certainty.

Chemical analysis showed that opalescent solutions contained more iron and manganese than those which were clear. Extreme iron deficiency could, however, be obtained in spite of occasional opalescence.

After the precipitate had been allowed to settle overnight, the supernatant liquid was transferred to tank 17 by means of the hose 15. The procedure purified about 150 gallons of water and this quantity lasted two days.

Tank 17, like 2 and 5, was coated heavily with bitumen paint before use and was provided with a sliding lid 16 of Holoplast to keep out dust. This lid also excluded light and so reduced the growth of algae, which otherwise tended to clog the apparatus, especially in hot weather.

On opening tap 18 the water flowed through PVC hose 19. Into this had been fitted eight polythene side tubes 20, each of which passed through the Holoplast lid of a mixing tank 21.

Preparation of nutrient solution.

The mixing tanks were tinned iron vessels coated heavily with bitumen paint and each lined with a polythene bag. A horizontal plan of the lid and a vertical section through one of these mixing tanks are shown in Fig. 4. Each polythene side tube 20 passed through the centre of the lid 27 and had on its end a short length of soft PVC tube that was cut carefully at right angles to its length. Just below this was a float 25, made from a sealed Perspex box. This was held by two short lengths of rod 23 passing freely through holes made in the lugs 24 fixed to the container. The float automatically stopped the flow when the right quantity of liquid was in the tank.

The upper half of a polythene bottle, when inverted and tightly fitted to the lid, formed a convenient funnel 26 for introducing concentrated nutrient solutions into the tank, while the lower half of the bottle was fashioned as a cap. A strip of Holoplast panel 22 was fixed across the lid to prevent it from sagging in the middle.

PLATE I.



FIG. 2.
Spray culture apparatus—general view.

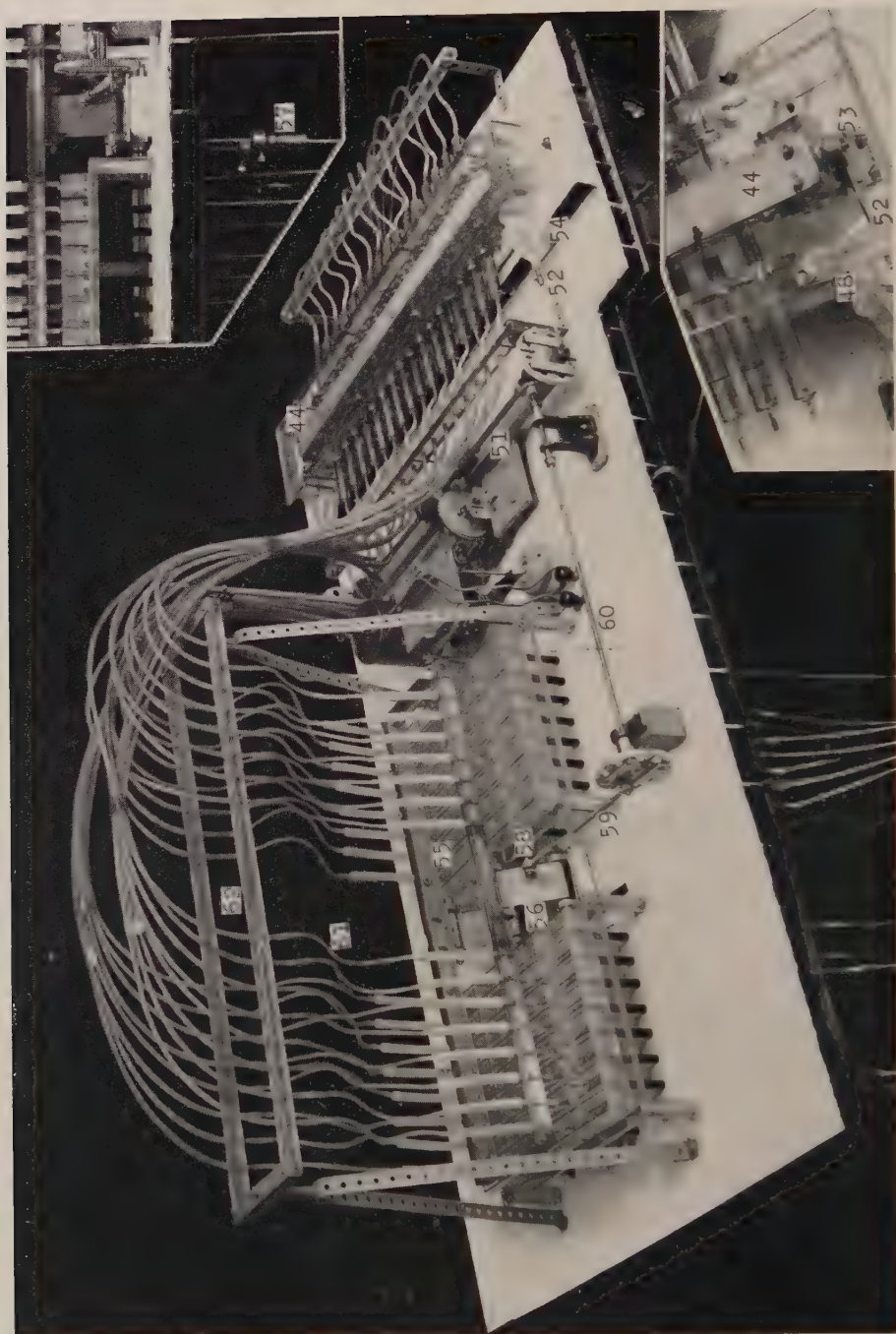


FIG. 6.
Dispensing unit.

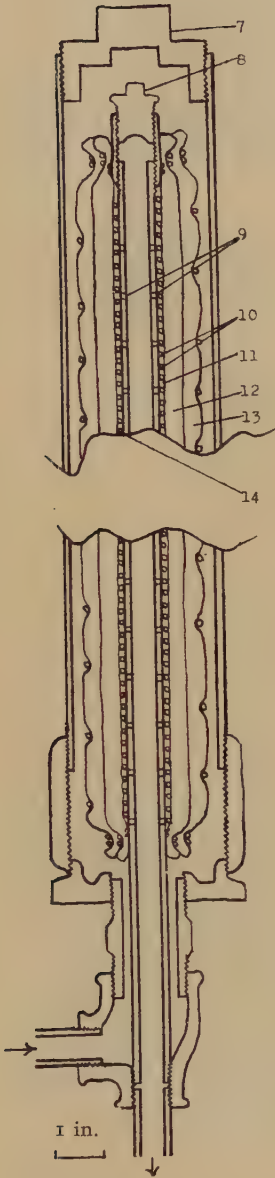


FIG. 3.
Water filter.

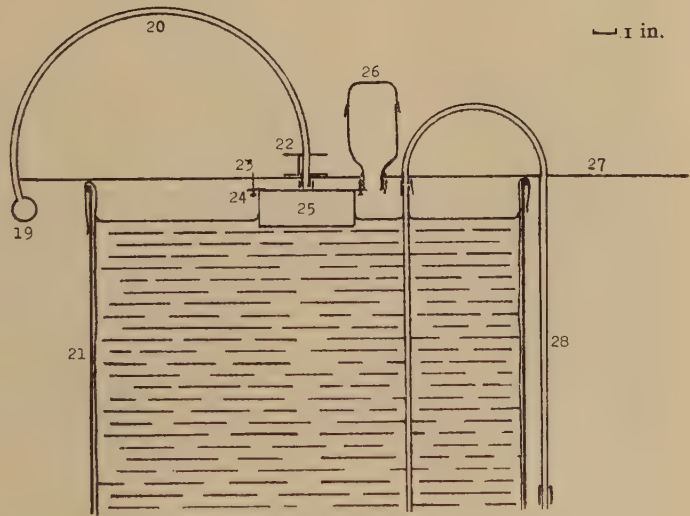
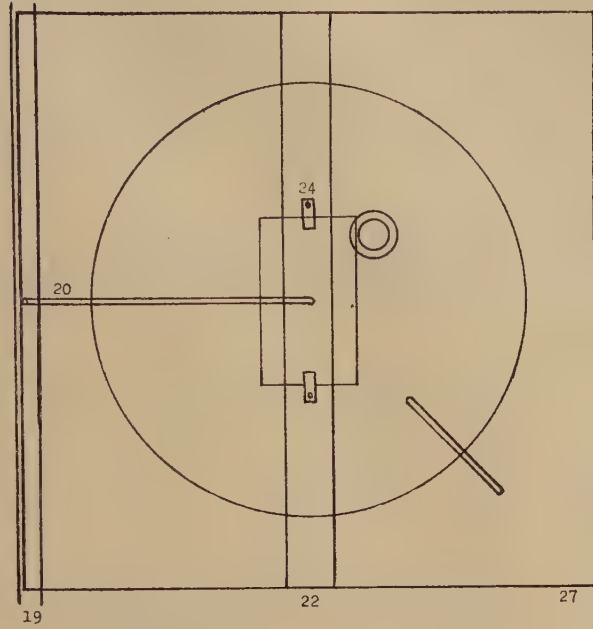


FIG. 4.
Nutrient mixing unit—plan of lid (top) and section through top (below).

The stock solutions of concentrated nutrients, when made up, were kept in the laboratory and so arranged and labelled as to minimize the risk of contamination. The nutrient solution was mixed by blowing down tube 28 (Figs. 1 and 4) after disconnection ; then a siphon was formed in this tube and it was reconnected and the contents of the mixing tank 21 flowed into the feed tank 29 (Fig. 1).

The feed tanks, after being cleaned thoroughly, were coated heavily with bitumen paint and lined with Sisalcraft paper, also coated with bitumen paint : inside this was a polythene bag as a liner. The purpose of the Sisalcraft paper was to protect the fragile polythene bag from any sharp protuberances or unevennesses on the surface of the tank.

The nutrient solution passed through a black polythene siphon tube 30 into the constant-level float chamber 31, a section through which on a larger scale is shown in Fig. 5. Since the purpose of this was to keep the level of liquid in the small feed

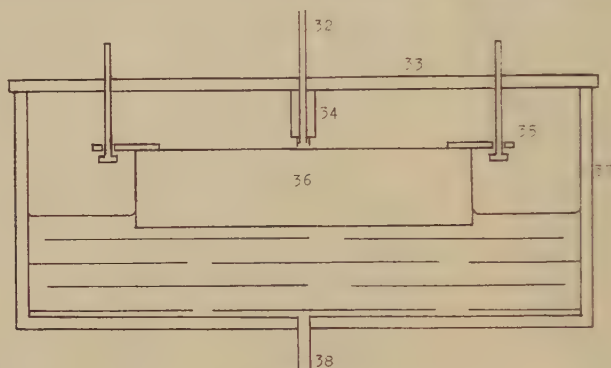


FIG. 5.
Constant-level float chamber.

reservoir 41 (Fig. 1) constant to within narrow limits, say within 1 mm., this float chamber had to be constructed rather more carefully than the constant level float already described for the mixing tank. The chamber 31 in which the float worked was of glass and covered by $\frac{1}{4}$ in. Perspex plate 33 (Fig. 5). The plate was held down by four bolts, not shown in the figure, passing through a horizontal piece of Holoplast panel. The polythene tube 32, after passing through the lid, passed through a Perspex collar 34 to hold it quite rigid. The collar was cemented to the lid. A short length of polythene tube protruded beyond this collar, and over this protruding end was fitted a short length of soft PVC tube, the end of which was cut carefully at right angles to its length to form an efficient cut-off when the float came in contact with it. Black polythene tubing 38 formed a push fit in a hole in the base of the glass vessel 37 and led the nutrient solution to the feed reservoir 41.

III. THE DISPENSING UNIT

(*W. A. Roach, R. Neve and F. H. Vanstone*)

The function of the dispensing unit was to pump a measured volume of nutrient solution from the little constant-level reservoir 41, (Fig. 1) into "pipette" tube 39, move this tube to the right along the path indicated by dotted lines and arrows,

and eject the solution into the receiving vessel 42₁. While tube 39₁ was taking up solution, tube 39₂, which was fixed to it by the rectangular frame 40, seen in end view in Fig. 1, was discharging into vessel 42₂; and when a little later 39₁ was discharging, tube 39₂ was taking up solution, and so on.

This alternate pumping up of liquid into tubes 39₁ and 39₂ resulted from the movement forward and backward of the two opposed pistons 47₁ and 47₂ respectively inside the fixed barrels 50₁ and 50₂ of two hypodermic syringes. The greater part of the length of the tubes connecting 39₁ to 50₁ and 39₂ to 50₂ is for simplicity represented in Fig. 1 by single lines. There were sixteen units such as the one just described.

For the pumps use was made of the glass parts of hypodermic syringes because of their ready availability. The greater uniformity of metal parts would have been an advantage. The enlarged head of each piston was clamped lightly between a perforated bar of Perspex 45 and a central solid block 46. Later it was found necessary to strengthen this composite beam by screwing on a plate of aluminium 44 on the top. The out-turned lip of each barrel was clamped lightly between two perforated plates of Perspex 48 and 49. The outer member 48 of each pair of plates also formed the two sides of a box enclosing a dust-free space to protect the piston surfaces. These were kept lubricated by graphite and oil.

A general view of the dispensing unit may be seen in Fig. 6 and a detailed view of one end of the part just described may be seen in the inset in the bottom right-hand corner.

The mechanism was driven by an electric motor of the same type and rating as that used for the spinning discs in the culture units. The constant voltage supply required has already been described. This was connected through a reducing gear to a shaft 51 (Fig. 6) which had at each end a crank, which moved forward and backward a rod 52. The latter was connected to each end of the beam just described with a ball bearing 53 (see bottom inset to Fig. 6). Each rod 52 passed through a hole bored in the Perspex side 48 of the box just described. Dust was excluded by means of a sleeve of thin polythene 54 attached to each rod at one end and to the lip of the hole at the other.

The mechanism for moving the pipette tubes forward and backward, with their ends alternately under the surface of the liquid in the reservoirs and over the receiving vessels, may also be seen in Fig. 6. The bottom narrow portion of each of the thirty-two pipettes passed through a hole in two Perspex bars to make a push fit. These two bars were fixed to a rectangular frame 55 made of angle metal. This frame was carried on two parallel plates 56, each of which was hinged at the top to the middle of one of the longer sides of the rectangular frame and at the bottom to the fixed base. Each of the four hinges consisted of a rod, fixed to the end of a plate, with ends protruding and passing through ball bearings, which were fixed to the frame and base respectively. The bottom pair of hinge rods also had, attached to one end, counterpoises 57 (top inset, Fig. 6). The front one of the two hinge-plates was also hinged through a ball bearing 58 with the shaft 59 of a crank, on the end of the shaft 60, which was driven by shaft 51 through bevel gear wheels. The connection between the pumps and the pipettes consisted of polythene tubing except for a few inches of elastic PVC tubing 61 to give the necessary pliability for movement of the pipettes. The polythene tubes just above the elastic PVC tubes passed through holes in a fixed rectangular frame 62 similar to the moving one already described.

The nutrient solution was led from the small receiving vessels to the culture units through black polythene tubing. At first it was arranged for the tubes to slope gently and continuously along their whole length. Soon, however, undulations appeared and siphons were formed, the periodic filling and emptying of which resulted in uneven flow of the liquid. It was then arranged for each tube to form a U, the lower, and greater, part of which was kept full of liquid. As liquid was fed into one limb it overflowed from the other. At the end of the 1954 season hydrochloric acid was passed through the tubes to remove any residue left by the nutrient solutions and this was washed out with water. At the beginning of the 1955 season care was taken to fill each U with a continuous column of water. Early in the season air bubbles were occasionally carried down into the first limb of the U, i.e., down the black polythene tubing leading from the bottom of the receiving vessels 42₁ and 42₂. The two ends of a length of narrow polythene tubing were cut at an acute angle and pushed down the black polythene tubes until the middle of the narrow tube rested on the plates separating the two receiving vessels 42₁ and 42₂, and an air hole was cut as shown in Fig. 1, 43.

IV. THE CULTURE UNITS

(H. J. Philcox, R. Neve and F. H. Vanstone)

The apple trees were grown in Holoplast structures 63 (Figs. 1 and 2), 3 ft. 6 in. in diameter and 3 ft. deep. The cylinder was made by riveting together two sheets 8 ft. $\times$ 4 ft. $\times$ $\frac{1}{16}$ in. thick, and this was secured to a 4 ft. $\times$ 4 ft. $\times$ $\frac{1}{8}$ in. thick base with pieces of angle metal. These structures were sunk in the ground to leave 6 in. protruding above the soil surface. The lid 65 was of $\frac{1}{2}$ in. Holoplast in the form of an octagon cut from a 4 ft. $\times$ 4 ft. sheet. The protruding top of the tub was surrounded by a ring of concrete 64 about 6 in. $\times$ 6 in., finished flush with the top of the lid so that the latter fitted snugly on the rim of the Holoplast cylinder and in a depression in the concrete. It was held down by turn-buttons secured to wooden blocks sunk in the concrete. The lids were painted white to reduce heat absorption from sunlight. In hot weather this was supplemented by placing papier-mâché partitions over the plain part of the lid immediately surrounding the motor house. More efficient insulating material might be an advantage.

The ring of concrete made a practically draught-proof and, therefore, nearly dust-proof junction with the lid. It protected the top of the tub from damage by feet and prevented treading the soil near the top of the tub and so creating excessive soil pressure on the Holoplast cylinder. One cylinder collapsed where a stone unduly concentrated this pressure. This was reconstructed with concrete, using a Holoplast cylinder suitably supported inside as an internal mould, and the soil, after an extra 2 in. thickness had been excavated, as external mould. This method of construction, i.e., of casting concrete cylinders *in situ*, would be considered seriously if a fresh start were to be made.

Each lid 65 had cut in it sixteen holes 5 in. in diameter with centres 1 ft. 3½ in. from the centre of the tub and distributed evenly around the circle so formed. Over the centre of the lid was housed a small motor 66, the shaft of which protruded through the centre of the lid and carried on its end a plastic disc 67 of 6 in. diameter. This was clamped between two small circular plates which were fixed to the shaft with grub screws.

Each apple tree was held in a stand illustrated in Fig. 7. The 6 in. diameter disc 68 of $\frac{1}{10}$ in. thick Holoplast fitted over the 5 in. diameter hole in the lid and was held down by two turn-buttons. Thus a practically dust-free and watertight cover was obtained but at the same time the whole stand and plant unit could be readily removed for examination and the trees removed from the stand for weighing, etc.

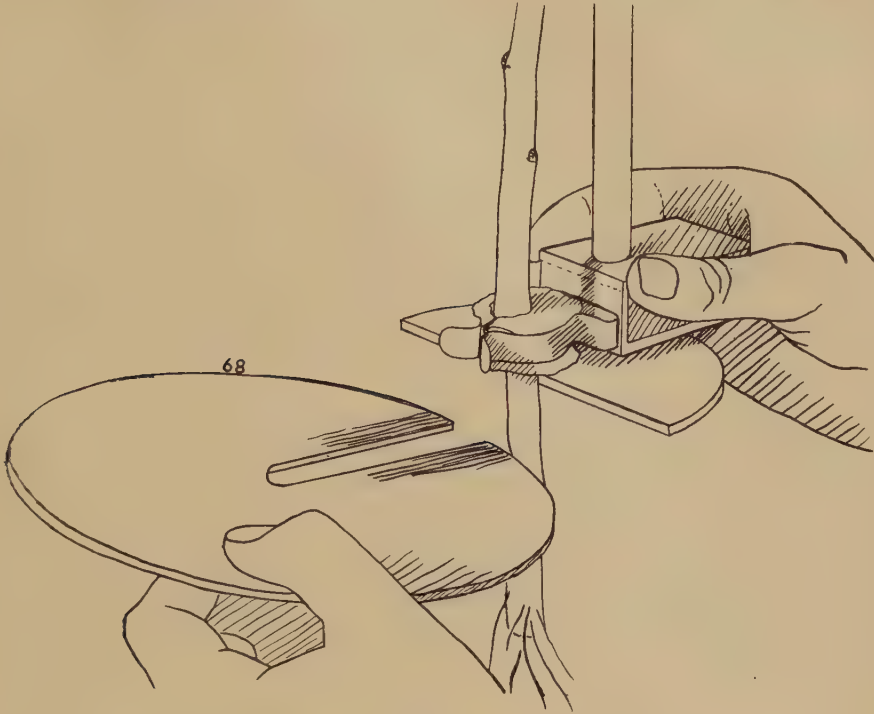


FIG. 7.
Plant stand, partly disassembled prior to removal of plant.

V. PRELIMINARY NOTES ON THE GROWTH OF ROOTED APPLE SHOOTS IN SPRAY CULTURE

(*Anne V. Delap and Elsie M. Ford*)

The spray culture method has been used to study the effects of different levels of nutrition on rooted shoots of apple rootstock M.VII.

The growth of the shoots, as compared with that of similar plants in soil, was satisfactory. In 1953 the plants in soil did not grow well because of the poor soil and infrequent watering; in that year those in spray culture were superior. Next year those in soil were much better treated. Growth was generally improved, but those in soil were only slightly superior to those in spray culture. In 1955 those in spray culture grew very well, possibly because of improvements in technique, but no plants were grown in soil to compare with them.

In the spray culture the leaves were similar in colour and texture to those of plants grown in soil and only the roots differed in appearance, these being long, fleshy and comparatively unbranched, unlike the fibrous roots formed in soil. There appeared to be no mycorrhiza present but the root hairs were long and abundant.

It was important to begin each experiment with as uniform material as possible and, since iron and magnesium deficiencies were to be studied, it was also desirable to reduce the reserves of these elements in the plants before applying treatments. The following procedure was therefore adopted. Plants were carefully selected on a weight and length basis and pruned to one-third their original length. All roots were removed, making it possible to assess the amount of roots formed in the course of the season with different treatments. After being "planted" in the containers and prior to applying treatments, the plants were grown for a preliminary period, first in water until roots were formed and then in nutrient solution from which iron and magnesium were omitted. In an attempt to reduce variability further, three buds were allowed to break on each shoot and of these the one which conformed most nearly to the normal was finally retained. A final selection of plants for uniformity took place at the end of this preliminary period. Despite these efforts to attain uniformity the remaining variability, which is considered to be largely inherent, was of the same order as is found among trees grown in the variable soil found in the field. As in the field, however, the variability was considerably reduced by statistical techniques involving correction by measurements made before the start of treatments. In spray culture these measurements were made at the end of the preliminary period.

The omission of iron and magnesium from the nutrient solution for the preliminary period was considered desirable in order to reduce the reserves within the plants. However, this was found to cause magnesium deficiency symptoms on the controls at a later date. To prevent this, the shoots of all plants were dipped weekly during this period in a 2 per cent. solution of magnesium sulphate. This was done in preference to adding the magnesium sulphate to the nutrient solution, which would have contaminated the nutrient reservoirs and supply tubes of the magnesium-deficient treatments.

Rootstocks planted during early April, when growth was slow, showed normal symptoms of iron and magnesium deficiency within eleven and fourteen weeks respectively, but when planting was delayed until May, when growth was faster, symptoms appeared within seven and ten weeks respectively. In June shoots were growing rapidly and, when healthy plants were moved from a full nutrient solution to one deficient in magnesium, symptoms of deficiency took only five to six weeks to develop.

It was possible to grow the same plants in the spray culture containers for a second and third year after over-wintering in sphagnum, peat or sand.

Spray culture shares with water and mist culture the following advantages over sand culture: (i) the roots can be examined easily, (ii) the fresh weights of the plants can be measured without damaging them, (iii) it is possible to alter quickly the composition of the nutrient solution reaching the roots, and (iv) plants can be moved from one treatment to another, with resulting quick responses. Further, since the nutrient solution is allowed to drain away, this system has an important advantage over water and sand cultures and over techniques involving re-circulation of nutrient solution in that there can be no fluctuations in pH or accumulations of ions or toxic products. Plants of apple rootstock M.VII grew well by this method,

although it had been found in the past that they were difficult to grow in water culture (Barker, 1921 ; Bird and Ruck, 1956). As with mist culture, the system has the disadvantage that a breakdown in the motors or in the supply of nutrient solution on a sunny day soon damages the roots by desiccation.

VI. PRELIMINARY NOTES ON THE EFFECTS OF MINERAL NUTRITION ON THE COMPOSITION OF VARIOUS PARTS OF APPLE SHOOTS GROWN IN SPRAY CULTURE

(*F. H. Vanstone*)

In the first season (1951) there were four different nutrient treatments: complete nutrient, low potassium, low iron and low manganese. At that time a quantitative development of a qualitative flame spectrographic method (Vanstone and Philcox, 1950) had proceeded far enough to give reliable values for potassium, iron, manganese and copper. It was, therefore, used for the analysis of over a thousand samples of leaf, bark, wood and root. Although it would be unsafe to draw more than tentative deductions from the results obtained, some of them will be given briefly because they indicate some future possibilities of the spray culture method.

One plant was taken at random from each of the four treatments at three-weekly intervals throughout the growing season, and on half of these occasions a duplicate plant was also taken. Leaves were analysed individually ; the current year's shoot was separated into wood and bark and the roots formed a fourth type of sample.

The results for potassium, iron and manganese on a dry weight basis are shown graphically in Figs. 8 and 9. Agreement between duplicates was so good that it was found unnecessary to plot the results for more than one of each duplicate pair to give a general picture of the results. In Fig. 8 the top row of curves gives the potassium contents of the leaves on the eight sampling dates. For each date there are four curves, each for a single shoot taken from each of the four treatments ; each point on a curve represents an individual leaf, so that each curve represents the change in potassium content of leaves from the base to the tip of a single shoot. The iron and manganese contents are represented in the second and third row respectively.

Potassium content.

The effect of the treatments began to show in the second sampling, when the leaves from the low-potassium treatment contained appreciably less potassium than those from the other three treatments ; this difference became progressively greater for the first four samples, after which it remained constant for the rest of the season.

There was little difference in potassium content from leaf to leaf along the stem in trees from the complete nutrient, low-potassium and low-manganese treatments throughout the season.

The results for the trees from the low-iron treatment differed markedly from those already considered. In the second sampling the low-iron curve was a little higher than those for the low-manganese and complete nutrient treatments. From the third to the sixth sampling inclusive, there was an increase in the potassium content of the leaves from the base of the shoot upwards, and the potassium content of the leaves in the upper half of the low-iron shoots was at least twice that for the

complete nutrient and low-manganese shoots. A similar, but less marked, difference was visible in the results for the seventh sampling, but at the eighth there was no longer any difference in potassium content between the three treatments.

Iron content.

The leaf samples were wiped with muslin, this being the routine method of cleaning. Soon, however, it was found that serious surface contamination often remained after this treatment and that washing in water with the addition of a little acid or detergent was necessary to remove all this surface contamination (Mason, 1953). The absolute figures would, therefore, be misleading and are not given, but certain comparisons may be drawn. First, it will be noted that the leaves from the low-iron treatment tended to contain less iron than those from the other treatments. The iron content of the leaves from the other three treatments tended to rise to a maximum at about the fifth sampling, especially in leaves on the lower half of the shoot, then to fall to about their original values at the end of the growing season. There was a slight tendency for the percentage iron content to be higher in the basal than in the terminal leaves at the first sampling; this increased to a maximum at about the fifth sampling, then decreased as the season advanced and disappeared, except in the leaves from the complete nutrient treatment, at the end of the season.

Manganese content.

At the first sampling the manganese content decreased markedly from the base to the tip of the shoot in all four treatments. As the season advanced the trend was less evident and had almost disappeared at the fifth sampling.

Even at the first sampling the younger leaves on the upper half of the shoot from the low-manganese treatment had a lower percentage manganese content than those from the other three treatments. This tendency increased as the season advanced until at the last two samplings the low-manganese curves were well below the rest.

There was marked basal defoliation in the low-manganese shoots from the fifth sampling onwards. There was a slight basal defoliation in the other treatments but much less marked than in the low-manganese treatment. This defoliation followed closely on the use of water that, accidentally, had not been neutralized.

The decrease in manganese content from the base upwards in the first ten leaves was most marked at the first two samplings and only slightly less so on the third and fourth. This was true of all four treatments. The content for the low-manganese treatment remained uniform from the eleventh leaf to the tip of the shoot for the rest of the season.

Perhaps the most interesting curves were those for the low-iron treatment. These, like the rest, started with a steep downward slope from left to right. Then, from the third sampling onwards, there was an increasing upward slope on the right until, at the seventh sampling, the curve assumed a pronounced U shape.

It will also be noted that the effect of treatment became increasingly apparent with time, so that at the end of the season the curves were almost completely separated.

Consistency of results.

These remarks are sufficient to indicate that the analysis of individual leaves of only single shoots taken periodically throughout a season gives a consistent picture of how the mineral content varies gradually from leaf to leaf up the shoot in any one

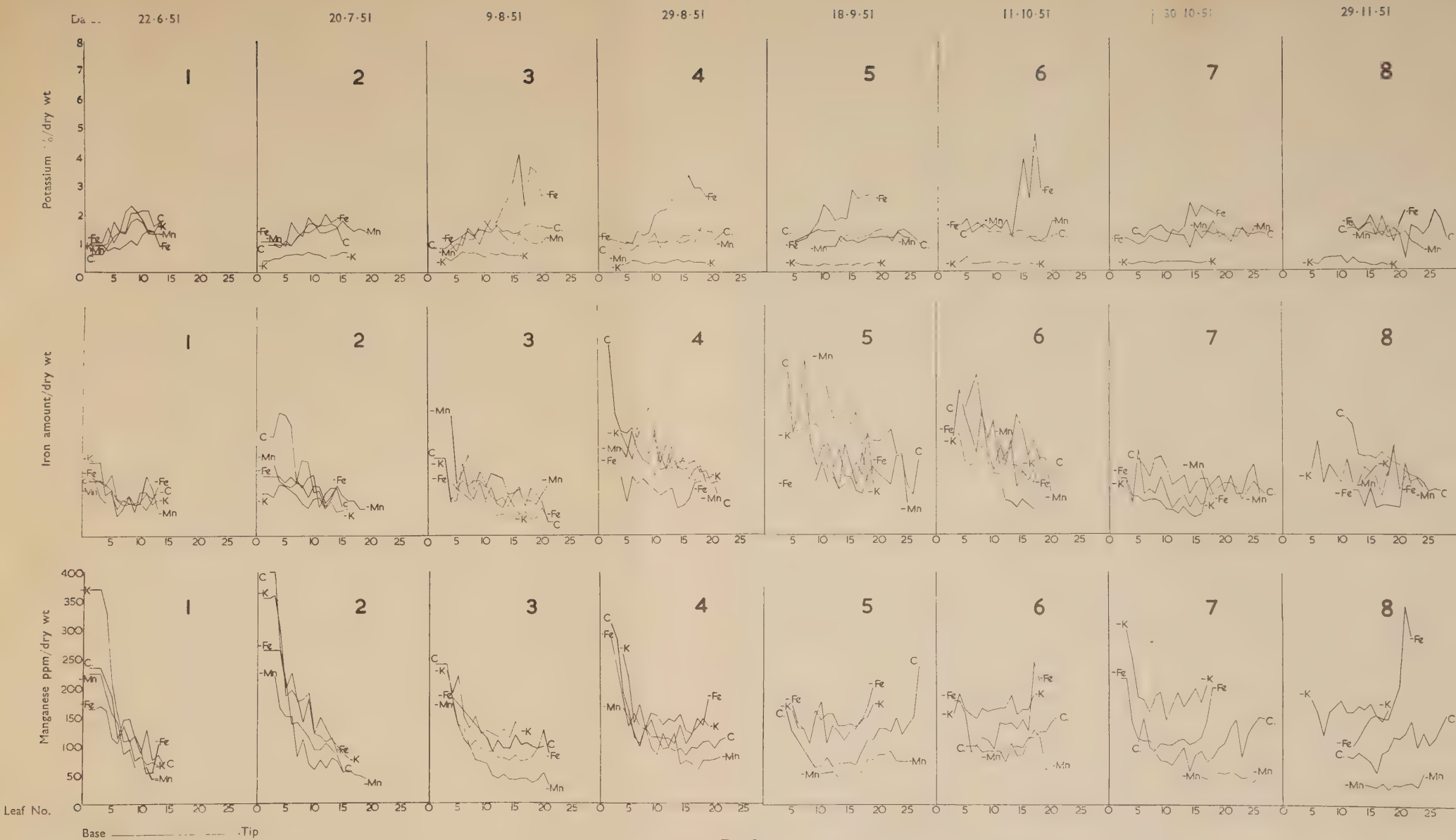


FIG. 8.
Mineral content (on dry weight basis) of individual leaves along the length of apple shoots for different treatments and different times of year.

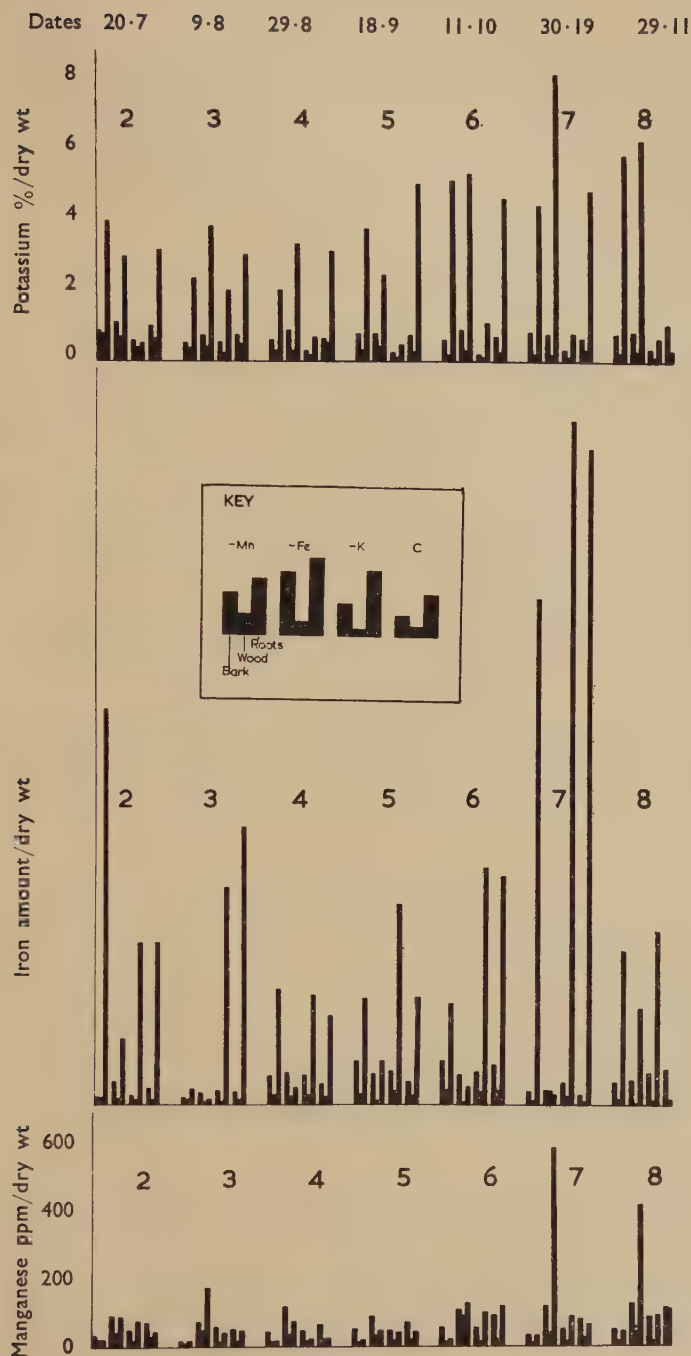


FIG. 9.

Mineral content (on dry weight basis) of bark and wood of current year's shoots and of current year's roots according to treatment and time of year.

shoot and how the type of this variation changes as the season advances. Each series of curves suggests a gradual change with season. There was close agreement between the results for duplicate shoots from the same treatment, the shape of the curves being closely similar, though the absolute values were smaller for small trees that made much growth and larger for large trees that made little growth.

Experimental error in the spectrographic analysis is sufficient to account for most of the leaf-to-leaf fluctuations of the curves. The few larger ones were associated with abnormality in leaf size, etc.

Similar trends may be seen (Fig. 9) in the results for wood and bark of current year's shoots and for the roots.

SUMMARY.

1. A method is described for growing a few hundred rooted apple shoots by spraying their roots with nutrient solution.
2. Growth was nearly as good as that made by similar shoots grown in soil under conditions approaching the optimum.
3. The roots were long and fleshy compared with the usual fibre development in soil. Root hairs were long and numerous. Mycorrhiza could not be found.
4. The roots were free from the bacterial and fungal slimes usual when apple trees are grown in water culture.
5. Spectrographic analysis of individual leaves revealed striking differences in mineral composition according to position on the shoot, time of year, and treatment.

ACKNOWLEDGMENTS.

Every member of the Biochemistry Section in 1951 contributed ideas or labour, and often both, to develop the method and keep the apparatus working. A special debt of gratitude is owed to the late Dr. A. E. Bradfield who took charge during W. A. Roach's absence of some weeks.

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STRAWBERRY CULTIVATION STUDIES

IV. DEVELOPMENTS IN MATTED SYSTEMS

By W. S. ROGERS and DOROTHY J. WILSON
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AN earlier paper in this series (Rogers and Modlibowska, 1950) showed that, with the variety Royal Sovereign, the natural runner habit of strawberries could become an asset, rather than a liability, in the commercial fruiting plantation. Matted rows or matted beds, formed by training-in the runners from the original plants, were shown to crop much more heavily than spaced single rows of original plants from which the runners had all been removed. In matted beds 36 inches wide, competition for soil moisture became acute in some years, and the difficulties of weed control and of access for thorough picking made them less satisfactory on the whole than the matted rows 18 inches wide.

It was therefore decided to test two modifications of these systems. Firstly, the matted bed deriving from two rows of plants was reduced in width to 24 inches and the alleyways were correspondingly narrowed. Secondly, matted rows and beds of the same size as in the earlier trials were made from fewer original plants, leading to a reduction in costs of planting and early cultivation; for it had been noted that plants at the former standard spacing of 36 in. $\times$ 18 in. produced many more runners than were needed to give mats of suitable density.

The four trials here reported continued the series on the variety Royal Sovereign and extended the tests to other varieties. The Royal Sovereign trial is dealt with first for convenience, although Trials II-IV were in fact earlier; in it a narrow matted bed was compared with matted rows derived from mother plants at different spacings.

Trials II and III with Huxley, and Trial IV with Auchincruive Climax, showed that the greater vigour of these varieties, resulting in more crowding of runners into the matted rows and beds, makes them more liable to water shortage than Royal Sovereign. The trials were not originally intended to investigate water relationships but, since wilting occurred, it was decided to irrigate part of each trial and this treatment gave valuable additional information. Trials II-IV were designed also to assess the effects of the post-cropping treatments, viz. cutting and burning, applied to large plots each of which included all the cultural systems. These treatments have already been described (Wilson and Rogers, 1954) and since they had no differential effects on the cultural systems they are not considered again here.

TRIAL I. MODIFICATIONS OF THE MATTED BED AND MATTED ROW.

Royal Sovereign runners were planted in October 1950 at the following spacings [Fig. 1(a), (b) and (c)] :

- | | |
|---|-----------|
| (a) Rows 36 in. apart, plants 18 in. apart in the row | } to make |
| (b) Rows 36 in. apart, plants 36 in. apart in the row | |
| (c) Rows 24 in. apart, plants 28 in. apart in the row, to make matted beds. | |

The spacing in the row of arrangement (c) was chosen to give approximately the same number of parent plants per acre as in (a).

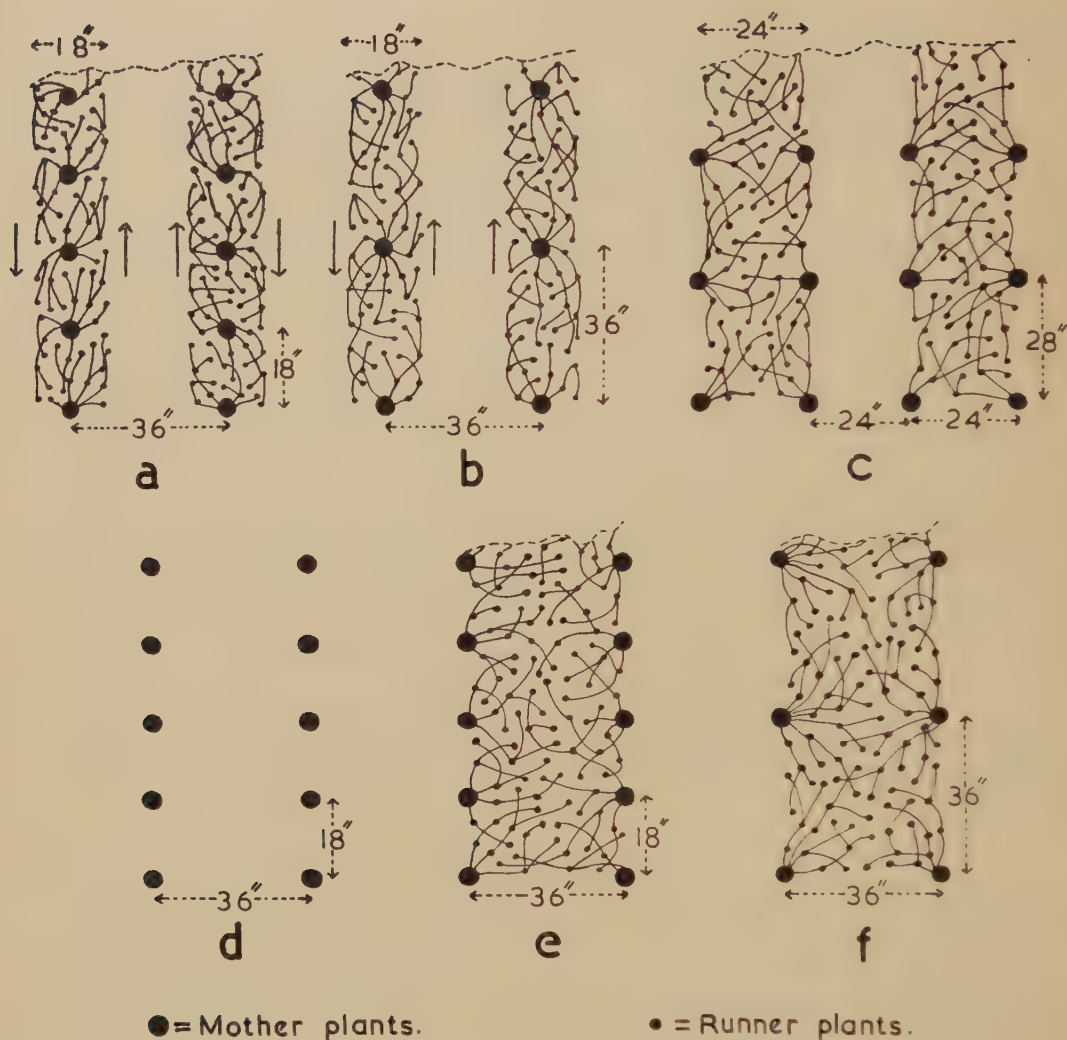


FIG. 1.

Spaced and matted systems tested in Trials I to IV.

- Matted row from mother plants 36 in. × 18 in.
- Matted row from mother plants 36 in. × 36 in.
- Narrow (24 in.) matted bed.
- Spaced single rows of original plants.
- Wide (36 in.) matted bed from mother plants 36 in. × 18 in.
- Wide matted bed from mother plants 36 in. × 36 in.

Each experimental plot contained two 6-yard rows of original plants so that, when the mats were completed, matted row plots consisted of two strips and matted bed plots of one strip; but because of the different spacings between rows, the matted beds were guarded by similar beds to give the correct alleyways on each side. All treatments were replicated ten times.

In 1951 the plants were deblossomed and the runners laid in where required. Matted rows were limited to a width of 18 in. and matted beds confined within the two parent rows. During winter cultivations the mats were straightened up and restricted to their prescribed width but in summer the foliage extended beyond these limits. Three successive crops were recorded and in the autumn of 1954 the plots were still in good condition.

Yield of marketable fruit.

The relative crops, in tons per acre, calculated for similar areas of all treatments, are given in Table I. There were no significant differences in yield of marketable fruit between the two forms of matted row. Whether they were derived from plants 18 in. apart or plants 36 in. apart, they cropped at the same rate throughout the trial.

The narrow matted bed behaved slightly differently. In the first cropping year it fell behind the matted rows and in the third year it exceeded them, but its total crop for the three years was not significantly higher than that of the matted rows.

TABLE I.
Marketable crops of Royal Sovereign in tons per acre.

Year	(a) Matted row from mother plants 36 in. $\times$ 18 in.	(b) Matted row from mother plants 36 in. $\times$ 36 in.	(c) Matted bed from mother plants 24 in. $\times$ 28 in.	Differences significant at $P=0.05$
1952	2.7	2.8	2.3	(a) > (c), (b) > (c)
1953	4.2	4.2	4.4	none
1954	4.2	4.2	4.8	(c) > (a), (c) > (b)
Total	11.1	11.2	11.5	none

TABLE II.
Percentage of grade 1 fruit (over $\frac{7}{8}$ in. diameter).

Year	(a) Matted row from mother plants 36 in. $\times$ 18 in.	(b) Matted row from mother plants 36 in. $\times$ 36 in.	(c) Matted bed from mother plants 24 in. $\times$ 28 in.	Differences significant at $P=0.05$
1952	29.8	33.7	24.6	all
1953	50.3	54.8	51.4	(b) > (a)
1954	33.0	35.4	32.9	none

Fruit size and quality.

Marketable fruit was graded at picking into two grades: 1, sound fruit over $\frac{7}{8}$ in. diameter and 2, all smaller sound fruit. Damaged and rotten fruit was also picked and weighed.

The amount of grade 1 fruit is given, as a percentage of the marketable crop, in Table II. It is notable that in all three years the matted rows derived from fewer parents had the highest percentage of grade 1 fruit.

The two types of matted row never differed significantly in the proportion of rotten fruit but the narrow matted bed had slightly less rotten fruit than either of them in the second and third crops.

Conclusions from Trial I.

The outstanding feature of this trial was the performance of the matted row derived from parents 36 in. apart. Earlier trials showed the superiority of matted rows over spaced single rows when the original planting was the same in both cases. But here an equivalent result was obtained although only half as many plants were used in the first place. The economic and practical considerations of this are discussed later.

The 24 in. matted bed has several practical advantages over the 36 in. beds used in earlier trials, but it yielded very little better than matted rows. If matted rows can be produced much more cheaply, little would be gained by using the matted bed as planted in this experiment.

TRIALS II AND III. HUXLEY GROWN IN MATTED SYSTEMS.

These two trials were of similar design, both of them comparing spaced single rows (here called spaced rows) with matted rows and wide matted beds. In Trial II all original plants were 18 in. apart in rows 36 in. apart [Fig. 1 (d), (a) and (e)]: but in Trial III matted rows and matted beds were both derived from plants 36 in. $\times$ 36 in. and the spaced rows remained at 18 in. $\times$ 36 in. [Fig. 1 (b), (f) and (d)]. Each experimental plot was 6 yards long and contained two rows of original plants. The treatments were randomized in guarded blocks, each being replicated twelve times.

Both trials were deblossomed in the first year and runners laid in to make matted rows 18 in. wide and beds 36 in. wide. Because of its vigorous growth, Huxley made very thick runner mats, even from parent plants a yard apart in the row, and it was difficult to keep them within the prescribed width. Edges were straightened during winter cultivation but summer foliage spread into the alleyways to an even greater extent than with Royal Sovereign.

Irrigation treatments.

Fairly severe drought was experienced during the picking periods of 1949 and 1951 and in these years wilting occurred, first in the wide matted beds, then in the matted rows and lastly in the spaced rows. The estimated mean soil moisture deficits (calculated for full cover) for the picking periods were: in 1949, 5.4 in.; in 1950, 4.1 ins.; in 1951, 4.7 ins. An inch of water was applied to half the plots in Trial II both in 1949 and in 1951 soon after picking had started. Half an inch of water was applied to half the plots of Trial III, in 1950 a week before picking began, and again in 1951 a week after picking began.

Yield of marketable fruit.

When Trial II was suffering from drought effects in 1949, the fruit in the matted beds was affected most severely (Table III) and the 1 in. of water applied to the irrigated plots was not sufficient to last for the whole of the picking season, which continued to be very hot and dry. In 1950 and 1951 water was less deficient and the matted systems surpassed the spaced rows in weight of crop. When it was freely available, on the irrigated plots in 1951, the matted beds utilized it most fully and produced the heaviest crop, as they had done in other years with Royal Sovereign.

Table IV shows that the yield of matted rows or beds formed from widely spaced mother plants in Trial III was not significantly different from that of an ordinary spaced row in the first year of cropping, but was significantly greater in the second. Again the beneficial effect of irrigation in the dry year 1951 was greatest where there was most competition, i.e. in the wide matted bed.

Fruit size and quality.

There were no significant differences between the treatments in percentage of grade 1 fruit, except in 1949. In that year of severe drought at picking time, the fruit from the matted rows and beds was markedly smaller than from the spaced plants and, although irrigation improved fruit size, it did so chiefly for the spaced plants.

There was a slight tendency for the matted systems to have a higher proportion of rotten fruit than the spaced plants but the differences were never statistically significant. It might well be expected that the "housed-in" condition of matted row and bed would encourage *Botrytis* rot but the disease was not severe in the years of these trials, and the tendency is probably due, in part at least, to the greater risk of leaving ripe fruits unpicked in the leafy mats, and particularly in the wide bed.

TABLE III.
Trial II. Marketable crop of Huxley in tons per acre.

Year		(d) Spaced row 36 in. × 18 in.	(a) Matted row from mother plants 36 in. × 18 in.	(e) Matted bed from mother plants 36 in. × 18 in.	Sig. Diff.	
					P=	P=
1949	Not irrigated	.. 3.0	2.4	1.2	0.4	0.6
	Irrigated 1 in.	.. 4.0	4.0	2.6	0.4	0.6
	Mean ..	.. 3.5	3.2	1.9	0.3	0.4
1950	Not irrigated	.. 3.1	4.6	4.4	0.5	0.7
1951	Not irrigated	.. 2.2	3.1	2.7	1.1	1.6
	Irrigated 1 in.	.. 3.3	4.9	5.8	1.1	1.6
	Mean ..	.. 2.7	4.0	4.2	0.8	1.1
Total ..		.. 9.3	11.8	10.5	1.2	1.6

Conclusions from Trials II and III.

Both these trials suggest that the variety Huxley is particularly sensitive to water shortage but that, when water is reasonably plentiful, matted rows and beds yield better than spaced rows. In fact, over the whole period of the trials, matted rows gave a heavier crop than spaced rows, even without irrigation.

Trials II and III give no direct comparison between matted systems formed from mother plants at 18 in. and at 36 in. in the row ; but Trial III shows that satisfactory matted systems can be formed from parents planted at 36 in. and that the yields are of the same order as those from closer parents, thus supporting the evidence of Trial I. There is a suggestion that the matted rows of Huxley from parents planted at 36 in. may not reach their full cropping power quite so quickly as those of Sovereign.

TABLE IV.

Trial III. Marketable crop of Huxley in tons per acre.

Year			(d) Spaced row 36 in. × 18 in.	(b) Matted row from mother plants 36 in. × 36 in.	(f) Matted bed from mother plants 36 in. × 36 in.	Sig. Diff.	
						P=	P=
1950	Not irrigated	..	3.9	3.6	3.8	0.9	1.2
	Irrigated $\frac{1}{2}$ in.	..	4.1	4.0	4.2	0.9	1.2
	Mean		4.0	3.8	4.0	0.6	0.9
1951	Not irrigated	..	2.8	3.4	3.5	0.7	0.9
	Irrigated $\frac{1}{2}$ in.	..	3.4	4.8	5.6	0.7	0.9
	Mean		3.1	4.1	4.6	0.5	0.7
Totals	Not irrigated	..	6.7	7.1	7.3	1.5	2.1
	Irrigated		7.5	8.8	9.8	1.5	2.1
	Mean		7.1	7.9	8.6	1.0	1.5

Since irrigation was applied in these trials only when the plants were visibly suffering from drought, it is not surprising that it had a large effect. Under Malling conditions, on a medium loam of $2\frac{1}{2}$ to 3 feet in depth, it is clear that, by the time the calculated soil moisture deficit (for full cover) reaches 4 in., irrigation is urgently necessary for strawberries. Several other irrigation trials with strawberries under less severe conditions have been carried out at Malling and consideration of the moisture availability, the root reservoir, the moisture tension and the evaporation rate, is best left until these trials are reported.

TRIAL IV. AUCHINCUIVE CLIMAX IN MATTED SYSTEMS USING FEW MOTHER PLANTS.

This trial was of the same type as Trial III, having plots of spaced rows at 36 in. × 18 in. and matted rows and beds derived from parents at 36 in. × 36 in. [Fig. 1 (d), (b) and (f)], all replicated 12 times. As with Huxley, the vigorous runner growth provided dense mats of plants and in 1951 competition for the limited water

supply resulted in severe wilting. Four replicates of all treatments were therefore watered on 7th July, four on 9th July and four left unwatered. However, 0.16 in. rain fell on 9th July and 1.4 in. two days later, so that only the plots watered on the first occasion had any great advantage over the controls. No irrigation was applied in 1952, although wilting occurred in that year, or in 1953. By spring 1954 the plantation was showing widespread streak and yellows, and both vigour and cropping were so greatly reduced that the experiment was terminated.

TABLE V.
Marketable crop of Auchincruive Climax in tons per acre.

Year		(d) Spaced row 36 in. × 18 in.	(b) Matted row from mother plants 36 in. × 36 in.	(f) Matted bed from mother plants 36 in. × 36 in.	Sig. Diff. P=0.05
1951	Not irrigated ..	5.3	4.6	4.3	0.9
	Irrigated $\frac{1}{2}$ in. on 7th July ..	4.9	5.9	6.0	0.9
	Irrigated $\frac{1}{2}$ in. on 9th July ..	5.1	4.8	4.6	N.S.
	Mean	5.1	5.1	5.0	N.S.
1952		4.0	4.1	2.8	0.3
1953		4.9	6.4	5.4	0.9
	Total	14.0	15.6	13.2	1.5

Yield of marketable fruit.

The crops are compared in Table V. In 1951, without irrigation, both matted systems cropped less well than the spaced row, the matted bed significantly so at the 5 per cent. level. Irrigation on 7th July was long enough before the rain to have an effect and both matted systems did significantly better than the spaced plants. As might be expected, irrigation made most difference to the wide matted beds. Irrigation on 9th July came too late to have much effect on total crop and no differences were significant.

Results in 1952 and 1953 were best from the matted rows, the wide matted beds falling far behind both other treatments in 1952 and only just exceeding the spaced plants in 1953.

Fruit size and quality.

Under the dry conditions of 1951 both matted systems had much less first grade fruit than had the spaced plants, whether watered or not, although the earlier watering gave some improvement. But in 1952 and 1953 differences in percentage of first grade fruit were too small for statistical significance. On the whole the wide matted beds produced more rotten fruit than the other treatments, but the percentage of rotten fruit was never high and the differences were small.

Conclusions. Trial IV.

This trial shows that, under conditions of adequate moisture, matted rows of Climax made from mother plants at 36 in. $\times$ 36 in. can yield more heavily than spaced rows of plants at 36 in. $\times$ 18 in. ; but that overcrowding of runners, even from such widely spaced parents, may lead to drought effects in some years. Varieties as vigorous and prolific in runner formation as Climax, before its decline from yellows, would probably do better if the runner plants could be limited (Rogers and Modlibowska, 1950). Nevertheless, over the three cropping years of the trial, the matted rows again produced more fruit than the spaced rows or the matted beds, even without irrigation.

DISCUSSION.

These trials have shown that, with the varieties Royal Sovereign, Huxley and Auchincruive Climax, matted rows and beds can be formed just as satisfactorily by planting at 36 in. $\times$ 36 in. as at the more usual distances of 36 in. $\times$ 18 in. Thus the costs of planting may be almost halved. Moreover, with the initial plants at 36 in. square, mechanical cultivation in both directions can be used until the runners need to be laid in, in June or July of the first season. This will reduce the cost of hand hoeing. Once the runners have started to form, cultivating each row always in the same direction will help to keep them in place [Fig. 1 (a) and (b)].

The importance of sufficient water has also been shown, even more clearly than in previous trials. Over the whole period of the experiments, matted rows have yielded more heavily than spaced rows, whether watered or not ; but in years of drought, matted rows have suffered more severely than spaced rows and 36 in. wide matted beds, especially of the variety Huxley, have suffered so severely that, with the added drawback of difficulty of management, they are clearly unsatisfactory. With Royal Sovereign the 24 in. matted bed did prove more promising, but the matted row is still easier to manage and therefore preferable on the whole. The importance of having the land free of weeds at the time the runners are laid in and of making sure that the runners are placed in position before they start rooting are practical points worth stressing.

The formation of matted rows from widely spaced parent plants is, so far as the authors are aware, a new cultural system and, before it can be recommended for general use, large-scale field tests are obviously desirable. Three growers have tested this method in fields of several acres, with the varieties Royal Sovereign, Climax and Talisman, and have reported satisfactory results. Thus, the matted row formed from an initial planting of 36 in. square should be economical and successful. For brevity, this method has been called the Hill-mat system (Rogers, 1950).

SUMMARY.

1. The use of the natural runner habit of strawberries to form matted rows and matted beds of the varieties Huxley and Auchincruive Climax is shown to lead to higher yields than are given by spaced rows of original plants, so long as soil moisture is adequate. This confirms previous findings with the variety Royal Sovereign.

2. In dry years, when the estimated soil moisture deficit (for full cover) exceeded 4 in. at strawberry picking time, wilting occurred first in the matted beds, next in the matted rows, and lastly in the spaced rows. Under these conditions, marked improvements in yield followed irrigation with $\frac{1}{2}$ in. or 1 in. of water. The improvement was greatest in the matted beds and rows.

3. Over the whole series of experiments matted rows yielded more heavily than spaced rows, whether irrigated or not. Matted rows are recommended for conditions similar to those at East Malling. Matted beds are not recommended because of the risk of wilting and the difficulties of management.

4. It was shown that matted rows and beds formed from mother plants 36 in. apart in the row (the Hill-mat system) yielded as well as those formed from mother plants only 18 in. apart in the row. This wider initial spacing will both lessen planting costs and allow cross cultivation for half the first season.

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SOME FEATURES OF THE BIOLOGY OF THE WINTER MOTH (*OPEROPHTERA BRUMATA* (L.)) ON TOP FRUITS*

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THE larva of the Winter Moth (*Operophtera brumata* (L.)) has been recorded attacking the foliage and fruits of nearly all temperate fruit plants and until recent years was a pest which gravely concerned fruit growers. A complete account of its habits and biology is not available in English ; information on hatching and on the behaviour of the newly hatched larvae, fundamental to the understanding of the successful action of some insecticides applied in the spring months, is extremely sketchy. The researches described here attempt to fill this gap, with special reference to conditions prevailing in south-east England.

THE EGG.

The eggs are ovoid, orange in colour and marked with a network of raised areas. A mixed collection of over 100 eggs from four sources in Kent and Berkshire, when measured with an eyepiece micrometer giving an error of ± 0.01 mm., varied from 0.53 to 0.67, with a mean of 0.61 mm., in length, and from 0.34 to 0.46, with a mean of 0.38 mm., in width. Silvestri (1941) stated that length varied between 0.60 mm. and 0.80 mm. and width between 0.38 and 0.44 mm. Eggs may be found singly or several together, in pruning cuts, angles and cracks, but hardly ever on smooth bark. Of 286 eggs laid by ten female moths in captivity only 4 per cent. were on smooth wood. Vogel *et al.* (1956) showed that nearly all were laid on vertical branches at the top of the tree. Schneider-Orelli (1915) found many eggs on the trunks of grease-banded pear trees ; the author found eggs in a similar situation on apple, some in places unlikely to be wetted by sprays.

Incubation period.

Field observations. Adult females were most abundant in the field at East Malling about 27th November, in the seasons 1952-3 and 1953-4. The peaks of hatching were on 14th April 1953 and 5th April 1954. If it is assumed that eggs are laid mostly at the time of greatest abundance of females, these figures indicate mean incubation periods of 139 and 130 days respectively. The mean temperature during both periods was near to 5° C. Grison and de Sacy (1948) give a period of 125 days for Versailles in France, at a mean temperature of 2° C.

Laboratory experiments. In laboratory experiments during 1951-4, performed in a shelter affording protection from sunlight, good agreement was obtained with the field data. Female moths collected in the field were confined singly, in hurricane lamp glasses covered with muslin, to lay eggs on suitable apple twigs ; any that laid less than 150 eggs were discarded, as it was considered that many of their eggs had

* Much of the information contained in this paper forms part of a thesis submitted to the University of London for the degree of M.Sc.(Hort.).

already been laid in the field. Seven families of eggs were retained in 1951-2, and ten in 1952-3 and in 1953-4. When the darkening colour of the first eggs showed that hatching was imminent the muslin was replaced by glass to prevent the escape of larvae. These were counted and removed daily or every other day. Results are presented in Table I, the incubation period of a family being considered as the interval between the dates when 50 per cent. of eggs were laid and a similar proportion had hatched.

TABLE I.
Incubation periods of families of eggs, in days.

1951-2			1952-3			1953-4		
Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
141	114	124	150	113	136	155	113	129

In general the first-laid eggs had the longest incubation period and the last-laid eggs the shortest, but there were exceptions; two families starting on 19th November 1951 had incubation periods of 125 and 141 days; five batches started on 28th November 1953 varied from 123 to 131 days. The possible significance of these variations will be discussed below in connection with hatching.

Effect of temperature. Kozhanchikov (1950) observed eggs incubating under controlled conditions. He considered that they developed faster with increasing warmth over the range -3 to 20° C. until diapause, that freezing was necessary to break the diapause, and that thereafter development was again accelerated by warmth within the range $5-25^{\circ}$ C. Mortality was lowest at 15° C. He gave time-temperature sums for each period. Grison and de Sacy (1948), however, reared eggs at constant temperatures without freezing and considered that there was only a "pseudo-diapause".

At East Malling, batches of eggs, all laid on 11th December 1952 and stored at field temperatures, were brought at weekly intervals, from 10th February until 7th April 1953, to a laboratory heated to about 20° C. Fifty per cent. of those brought in on 10th February had hatched in 14 days; on 16th February, in 12 days; and progressively less until 7th April when the remainder outside started to hatch. This suggested that eggs were developing in the field during the whole of this period, their increasing maturity at each stage being reflected in the shorter period required for hatching at the laboratory temperatures.

Hatching.

Laboratory studies. In 1950-1 two apple seedlings, under lamp glasses with muslin covers, were each infested on 8th November with six female moths. About 250 eggs were laid on the muslin cover of one, but few on the other. On 24th November the second was infested with a further nine females; about 100 eggs were laid on the muslin. These eggs were stored at field temperatures and examined frequently from 15th March onwards for the presence of hatched eggs which were removed and counted. Fig. 1A illustrates the results; distinct hatching curves were obtained from each set of eggs.

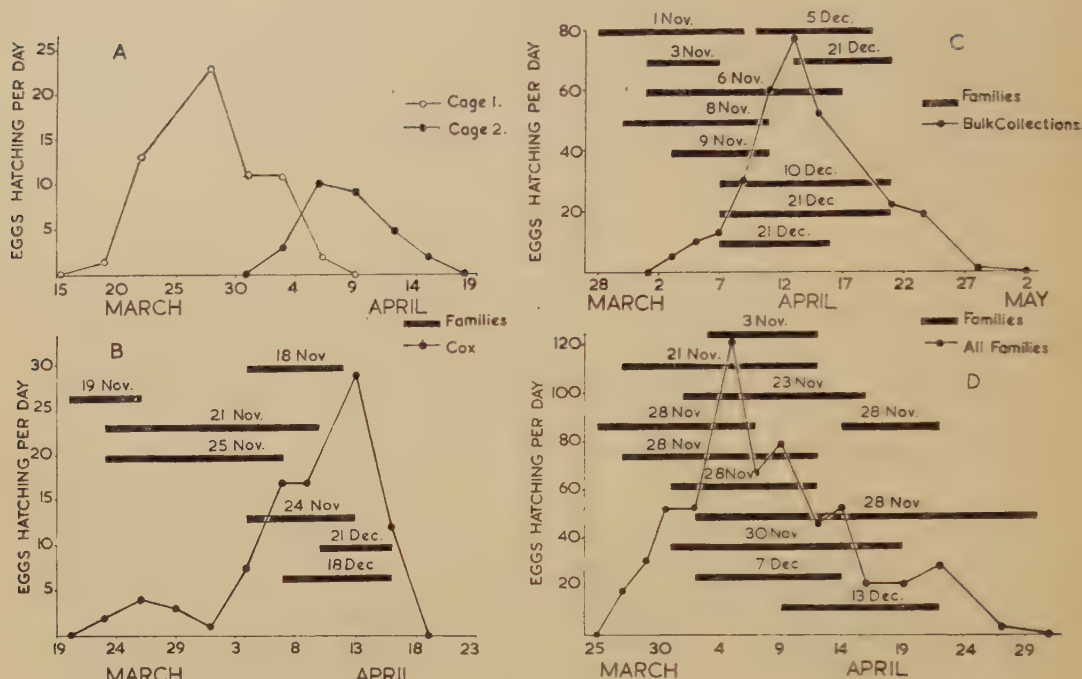


FIG. 1.

Hatching times of eggs laid in the insectary, 1951-4.

- A, Number of eggs hatching per day in two cages, 1951.
- B, Duration of hatching period of eggs of various families, and number of eggs hatching per day on a potted tree of Cox's Orange Pippin, 1952.
- C, Duration of hatching period of eggs of various families, and number of eggs hatching per day in bulk collections, 1953.
- D, Duration of hatching period of eggs of various families, and number of eggs hatching per day in combined families, 1954.

In 1951-2, since it seemed from the 1950 experiment that the origin of the eggs might influence their time of hatching, a total of 30 females, collected over as much of the flight period as possible, were used to infest a potted apple tree. The total of about 1,000 eggs which these moths laid had to be reduced to about 300 to eliminate masses where the subsequent removal of hatched eggs would lead to damage to or removal of their neighbours. The hatching period of the remainder, determined by frequent inspection and removal of any that had hatched, is illustrated by the continuous line in Fig. 1B. The interruption of the upward trend in numbers hatching per day at the end of March related to an exceptionally cold period when snow fell.

To investigate more fully whether the different hatching periods of two batches of eggs in 1950-1 were due to variations in environment, time of origin, or parentage, single female moths collected at various times throughout the flight period of 1951 were caged, with cut shoots of apple, in lamp glasses covered with muslin; the eggs

laid by each were stored at field temperatures and are subsequently referred to as "families" of eggs. The durations of the hatching periods of these families in 1952 are illustrated by the horizontal lines in Fig. 1B. The date above each line indicates the middle of the egg-laying period, which, however, was always a compact one of three to four days. In general, the earliest and latest laid families were respectively the earliest and latest to hatch, which is in line with the concept of time-temperature constants controlling the length of incubation put forward by Kozhanchikov (1950). However, the widely differing hatching periods of the families of 18th and 19th November and the shortness of the hatching period of any family relative to that of the remainder suggested that some other factor was operating, and it was considered that this was either variable incubation conditions or parentage of the eggs.

In the absence of facilities for controlling the environment of the eggs during incubation, an attempt was made in 1952-3 to compare directly the effect of parentage with that of environment. Further families of eggs were reared as described above, but in addition three batches, of mixed parentage but of similar origin in time, were reared by placing several female moths in each of three lamp glasses on 16th November 1952. All had laid eggs and were removed by 20th November. These were termed bulk collections. The hatching periods of ten families are illustrated in Fig. 1C in the same way as for the previous year. The curve represents the total number of eggs hatching per day in all three bulk collections. Individual bulk collections hatched over periods of from 8 to 27 days with a mean of 20 days while individual families hatched in from 6 to 16 days with a mean of 10.25 days. Further rearings of families of eggs in 1953-4, results of which are presented in Fig. 1D, showed that among families of eggs of similar origin in time (28th November) there were wide variations in hatching period.

The following hypothesis is suggested to explain these facts. Each female parent imparts to her eggs some character which, within the limits of the environmental conditions prevailing, determines the length of their incubation. Thus *within* families of eggs, variability in incubation period is low and a compact hatching period results. *Between* families of eggs, however, variability in incubation period is higher, and a long hatching period results as for the "bulk collections" of the experiment of 1952-3. While the existence of an inherited character could only be tested conclusively by rearing selfed lines of moths through several generations and under controlled conditions, this hypothesis is in line with the findings of Speyer (1938a) who reared races of the Winter Moth collected in different parts of Germany and found that the incubation period of the eggs in each race varied. Indeed, it is known that eggs incubate for about 2 months in Italy and for 6 months in Finland, and there seems no reason to suppose that variations similar to these, but of lesser order, should not exist in a single population.

The effect of sprays on such a population might have interesting results, especially as it is known that the eggs of certain insects and mites become more susceptible to the action of ovicides during the later stages of incubation. This was demonstrated by Chancogne *et al.* (1949) with eggs of the Winter Moth and the ovicidal material sodium dinitrocresylate. If such a material were used at the same stage for several years, it might result in inferior control, the susceptible part of the population in which the egg was most mature at the time of spraying having been killed, while the less susceptible later hatching types would survive from year to year.

Field observations. From 1953 to 1956 hatching in the field was studied by

collecting buds at intervals from unsprayed trees and counting the larvae in them at each date. In 1953 one hundred, and in 1954 two hundred wood buds of Early Rivers cherry were used; in 1955 and 1956 two hundred fruit buds of Lane's Prince Albert apple. After 1st May 1956 this sample was reduced to one hundred buds because of the abundance of larvae. The results (Table II) show that the number present does not always rise steadily; day-to-day fluctuations, probably caused by contemporaneous hatching and dispersal, make interpretation of the results difficult. However, peak hatch apparently occurred about the 13th, 7th, 11th and 21st April in the respective years of the period 1953-6.

In 1954 greased plates were exposed in the same orchard, primarily to find if dispersal of larvae on the wind took place. With one exception all the larvae taken on these plates appeared to have been recently hatched. Such larvae were caught between 27th March and 24th April, with greatest numbers about 7th April. This date agrees closely with that for peak hatch arrived at from the bud sample.

TABLE II.
Number of Winter Moth larvae in sample unit of buds.*

Date	Number of larvae			
	1953	1954	1955	1956
27th March ..	—	0	—	—
28th " ..	—	—	—	0
29th " ..	—	1	—	—
31st " ..	—	2	—	—
2nd April ..	—	4	—	—
3rd " ..	—	—	—	1
4th " ..	—	—	0	—
5th " ..	0	4	—	—
6th " ..	—	—	—	1
7th " ..	4	13	0	—
9th " ..	16	12	—	3
11th " ..	8	—	—	2
12th " ..	—	8	14	—
13th " ..	25	—	—	11
14th " ..	—	13	—	—
15th " ..	0	—	12	—
16th " ..	—	10	—	3
17th " ..	11	—	—	—
18th " ..	—	—	—	9
19th " ..	—	13	15	—
21st " ..	21	—	—	28
23rd " ..	—	—	—	24
24th " ..	30	—	—	—
25th " ..	—	—	—	34
28th " ..	21	—	16	42
1st May ..	—	—	—	29†
2nd " ..	27	—	—	—
3rd " ..	—	—	—	33†
4th " ..	—	—	—	—
5th " ..	—	—	—	26†

* In 1953 and 1954, wood buds of Early Rivers cherry; 100 buds in 1953 and 200 in 1954. In 1955 and 1956, fruit buds of Lane's Prince Albert apple; 200 buds in both years.

† In 100 buds.

Conclusions. Table III summarizes the dates for first hatch, peak hatch and end of hatch in 1952-6 inferred from the various methods used. Figures for peak of hatching amongst combined families of eggs are not included since these might give misleading results.

During the seasons 1952-6 the stages in fruit bud development, as described in the Ministry of Agriculture Bulletin No. 137, were recorded for the fruit varieties Worcester Pearmain and Bramley's Seedling apple, Conference pear, Myrobalan and Czar plum, and Bigarreau de Schrecken cherry. These are set out in Table IV relative to the start, peak, and end of hatching. From these data it is clear that the hatching period varies slightly from year to year in relation to bud development of any given variety. The most consistent relationships were with the full bloom stage of Myrobalan plum for the start of hatching and with the burst stage of Conference pear for the peak. However, hatching normally began when the buds were between the swelling and burst stages of the apple, pear, Czar plum, and cherry; peak hatch had normally occurred by the mouse ear stage on the apple, burst stage on the pear and burst to white bud stages on Czar and Bigarreau de Schrecken, and was generally complete by the green cluster stage on the apple, white bud on the pear, and full bloom on Czar plum and cherry. Hatching had not started at the delayed dormant stage when ovicides are usually applied, but was sometimes incomplete at white bud on Czar and Schrecken when larvicidal spring washes are usually applied.

TABLE III.
Hatching dates, 1952-6.

Experiment	Start	Peak	End
1952			
Potted Cox's Orange Pippin	20th March	10th April	16th April
All families	20th March		16th April
1953			
Bulk collection	1st April	14th April	24th April
All families	28th March		21st April
Bud collection	5th April	13th April	24th April
1954			
All families	25th March		12th April
Bud collection	27th March	7th April	14th April
Greased plates	28th March	7th April	24th April
1955			
Bud collection	7th April	10th April	12th April
1956			
Bud collection	1st April	21st April	1st May

THE LARVA.

Behaviour.

Speyer (1941) described the larva of the Winter Moth with details of its morphology. Stokoe (1948) gives a brief description in English.

The site at which larvae may be found feeding bears more relation to the stage of development of the buds than to the age of the larva. On apple, for instance,

buds at the breaking stage may be tunnelled by newly hatched larvae ; at burst, larvae are between unexpanded rosette leaves and developing blossom buds ; at mouse ear, the vegetative buds may have expanded sufficiently for the larvae to penetrate ; at green cluster, most of them are feeding on one of the leaves of the cluster, their presence often being indicated by its failure to expand ; at pink bud, some are in the blossoms feeding on the stamens and pistil. Attacked flowers may fail to open. At full bloom and thereafter, larvae may be found on leaves of the spur and extension growth and may attack developing fruitlets. On other hosts the mode of feeding is again largely dictated by availability of tissue ; thus on cherry the vegetative buds, which open first, are attacked earliest.

TABLE IV.

Stages of development of various hosts during hatching of Winter Moth eggs.

Stage of hatching	Worcester	Bramley	Conference	Czar	Myrobalan	Schrecken
Start						
1952	SW*	SW	SW	SW	FB	SW
1953	BU	ME	BU	BU	FB	BU
1954	SW	BR	SW	SW	FB	SW
1955	SW	BR	BR	SW	WB	SW
1956	BR	BU	BR	BR	FB	SW
Peak						
1952	BR	ME	BU	BU	PF	BU
1953	ME	GC	BU	WB	PF	WB
1954	BR	ME	BU	BU	FB	BU
1955	BR	BU	BU	BR	FB	SW
1956	ME	ME	GC	BU	PF	BU
End						
1952	ME	GC	FB	FB	F	FB
1953	PB	GC	WB	FB	F	FB
1954	ME	ME	GC	WB	PF	BU
1955	BU	ME	BU	BU	FB	BR
1956	GC	GC	WB	FB	F	FB

* Abbreviations used : SW, swelling ; BR, breaking ; BU, burst ; ME, mouse ear ; GC, green cluster ; PB, pink bud ; FB, full bloom ; PF, petal fall ; F, fruitlet ; WB, white bud (plums and pear).

Though a dispersal of the larvae on the wind shortly after hatching has long been assumed, there seems to be no direct evidence that this takes place, although Soenen (1950), in an interesting study, investigated the possible mechanisms of dispersal in this species and by elimination suggested that dispersal of the young larvae was the only explanation of the records obtained in his study. On 20th March 1954, glass plates smeared with oil were suspended in the branches of standard sweet cherry trees and on poles between them, at horizontal distances of from 5 to 15 feet from the nearest foliage, according to the spread of the trees. Some faced north and south, others east and west. A total of 130 first instar larvae were caught between 27th March and 23rd April with highest numbers between 3rd and 10th April, when hatching was at its peak. As might be expected, larger numbers of larvae were trapped on the plates suspended in the branches ; obviously the density

of dispersing larvae in the air will tend to decrease with distance from the source. No correlation was found between numbers trapped per day and wind speed, nor between numbers caught on each aspect with wind direction. However, there were calm periods on nearly every day throughout this period. Before the importance of dispersal in creating new infestations can be gauged, much more information than that supplied by this experiment on the density of larvae in the air at various distances from a source must be available.

Rate of development.

The rate of development of larvae in the field was assessed by collecting, at frequent intervals, all those present in 100 buds (in 1953) and 200 buds (in 1954) of the sweet cherry variety Early Rivers, in an orchard near East Malling. The larvae were preserved and the instar to which they belonged subsequently found by measurement of the head width. The number of larvae in each sample are shown in Fig. 2; the points have been joined as a graph to illustrate the trend. Numbers

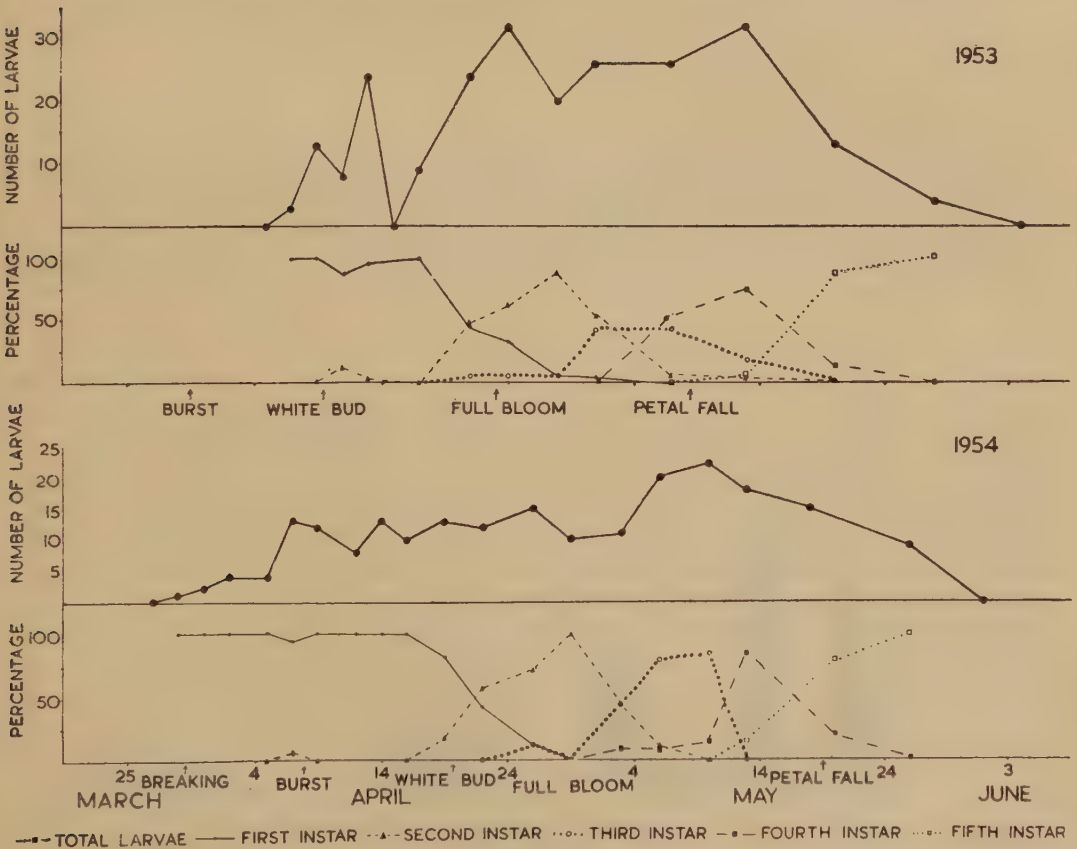


FIG. 2.

The number of larvae, and the percentage belonging to each instar, at each time of sampling of cherry buds, 1953 and 1954.

were variable during the hatching period, then fairly constant until mid-May when the first larvae left the tree to pupate.

Fig. 2 also shows the rise and fall in the proportions of each instar present in each collection, and thus the period over which each instar is present and which one is predominant at a given time. Stages in cherry fruit bud development are shown beneath, at the time at which most buds were at the stage indicated, since there is much overlapping of bud stages on a single tree. Judged by the intervals between peaks in Fig. 2, the approximate durations of the middle instars were: second, 11 and 13 days; third, 9 and 11 days; fourth, 6 and 3 days, for 1953 and 1954 respectively.

To investigate whether development varied with locality and season, other collections were made from various fruit varieties in 1952-4 at East Malling, and in 1954 from apple trees of mixed varieties at Ulcombe, Kent. After the first instar, the percentage of larvae per instar at any date on any host was very similar from year to year at East Malling, with the exception of larvae collected from a very sheltered situation. The collections made at Ulcombe, however, showed that in 1954 the development of the larvae was consistently from 4 to 7 days behind that of the larvae at East Malling.

Larval head width.

Measurements of the head widths of field-collected larvae were supplemented by measurements of the dry cast head capsules of reared larvae. Fig. 3 is a frequency distribution showing larval head widths; the five peaks show the five larval instars. The measurements are in broad agreement with the findings of Dyar (1890), viz., that the widths of the heads of certain Lepidopterous larvae fall into groups by

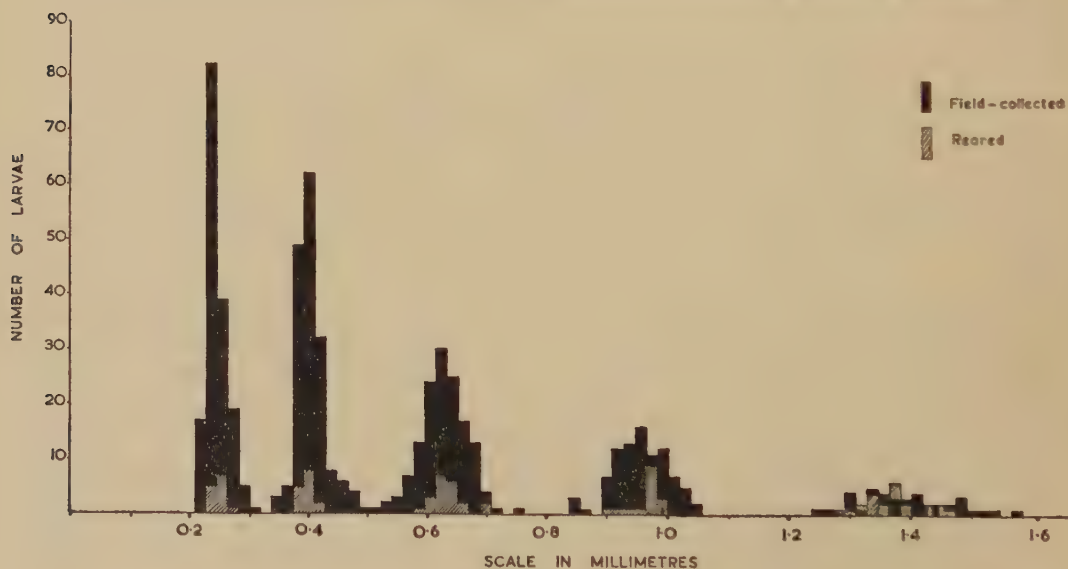


FIG. 3.

Frequency distribution of the widths of the heads of field-collected larvae, and of the head capsules of reared larvae.

instar, the means of which form a geometric progression. Table V shows, in the first column, the mean head widths of the larvae of the field collections ; in the second column, calculated values which form a geometric progression of which the first and last values are those obtained from the field sample ; in the third column, the data obtained from the reared larvae. The data in the three parallel columns of Table V are in very close agreement.

TABLE V.
Mean head width of each larval instar in mm.

Instar	Field larvae		Reared larvae
	Observed	Calculated	
I	0.26	0.26	0.26
II	0.42	0.40	0.42
III	0.65	0.61	0.66
IV	0.99	0.94	1.00
V	1.44	1.44	1.43

THE PUPA.

Massee (1947) suggested that a year of heavy larval damage following one when damage was light might be explained by some pupae "lying over" the previous winter. Grison and de Sacy (1948) and Kozhanchikov (1950) considered that there was a pupal diapause, which would allow of such a phenomenon, but Speyer (1938*b*) considered that there was no interruption of physiological processes. In the author's rearing of limited numbers of adults no emergence after two summers has been recorded.

THE ADULT.

The morphology of the adult is described by Speyer (1940). Barrett (1902) gives a description in English. Probably because of the earlier emphasis placed on control by greasebanding, much more work has been done on the adult than on the immature stages of this insect. The time of first emergence, ranging from September in the north to December in the south, is known for nearly all areas of Europe. Most authors agree that the males emerge slightly before the females. Activity is reported by Hiddinck (1950) during daylight on misty days ; other authors report activity about sunset. Williams (1935) trapped most males at a light trap during the first few hours of darkness, but others came to the light all through the night. Some authors consider that flight *in copula* takes place.

The females have been reported by various authors to lay maxima of from 200 to 350 eggs ; consensus of opinion seems to be that a mean of about 150 eggs is laid.

Behaviour.

Shortly after emergence, female moths climb the trunks of the host trees. By marking the position of female moths during the daylight hours, some diurnal movement was demonstrated from these points. However, larger numbers were observed moving up the trunks immediately after nightfall. Males, which are

occasionally observed resting on trees and fence posts during the day, appeared in numbers a few minutes later. They behaved as if chemotactically attracted to the females, alighting on the trunk and crawling upwards along the path of a female, with rapid movements of the antennae. Copulation often took place on the upper part of the trunk but has been noted lower down and on orchard herbage. Flight *in copula* has not been observed. Females after fertilization continue the ascent to the more distal parts of the branches; egg-laying takes place soon after and the effective life of the female is probably normally complete after 2 or 3 days.

Emergence and flight period.

Laboratory studies. Although large numbers of larvae were collected and fed to maturity in 1951, 1952 and 1953, only 49, 111 and 94 adults were reared to maturity in the respective seasons. Table VI summarizes the results.

TABLE VI.
Date of emergence of proportions of adults.

		1951	1952	1953
First emergence	Males	5th Nov.	18th Nov.	20th Oct.
	Females	16th Nov.	19th Nov.	26th Oct.
50 per cent. emerged	Males	16th Nov.	3rd Dec.	19th Nov.
	Females	23rd Nov.	11th Dec.	26th Nov.
Last emergence	Males	8th Dec.	23rd Dec.	12th Dec.
	Females	15th Dec.	29th Dec.	11th Dec.

Most moths emerged in daylight, as Speyer (1938a) stated. Male emergence took place over a period a little earlier than that of the females. Zirnits (1933) suggested that frost initiated emergence. However, in 1952 emergence was late when frosts were frequent, whereas in 1953 a mild autumn coincided with the earliest emergence, with no air frost until emergence was under way. Moreover, comparison of the numbers emerging per day and the minimum temperature for that period showed that, for males, on 17 occasions when the minimum was below 27° F., an average of 0.2 moths per day emerged; whereas on 107 occasions when it exceeded 27° F., 0.9 moths per day emerged. In the case of the females, the corresponding figures were 0.3 and 1.5 moths per day. The evidence, therefore, shows that frosts neither initiate nor encourage emergence but inhibit or delay it; the day-to-day variations in numbers trapped in the field were entirely consistent with this view.

Emergence of females in the field. In attempts to assess the seasonal variation in abundance of female moths, tapping branches over a beating tray and visual inspection produced numbers too small to be of use. Greasebands and traps on the trunks of trees were used, but these gave no indication of the numbers of moths that were present on the higher part of the tree; results obtained in this way could, therefore, only be used as a measure of emergence.

In 1951 and 1952 the trunks of 78 trees in a mixed unsprayed orchard of apples, pears, plums and cherries were smeared at 5 feet from the grass below with greasebanding 3 inches deep; 10 trees had a similar band applied 6 inches higher. One

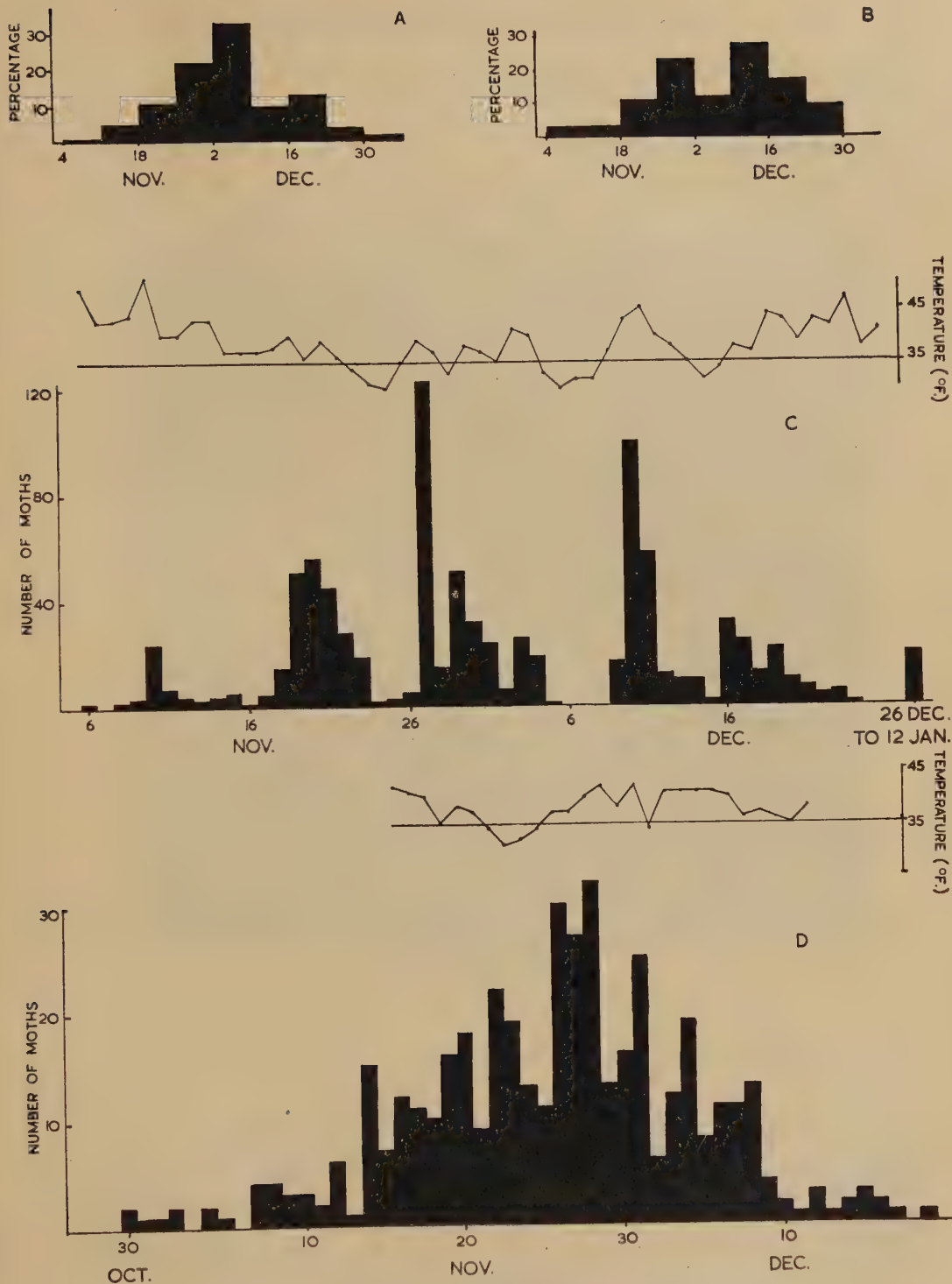


FIG. 4.

Emergence of female moths in the field, 1951-4.

- A. Percentage of total emerging per week, on greasebands, 1951-2.
- B. Percentage of total emerging per week, on greasebands, autumn 1952.
- C. Number of individuals emerging per day, in traps, 1952-3, with mean temperatures for 10 a.m. to 4 p.m.
- D. Number of individuals emerging per day, in traps, autumn 1953, with mean temperatures for 10 a.m. to 4 p.m.

hundred and twenty-eight females and 52 males were caught in the first season, and 159 females and 126 males in the second. Only about 1 per cent. were caught on the upper bands. Results, expressed as the percentage of the total females trapped per week, are shown in Figs. 4A and 4B.

In 1952 and 1953 traps were placed on the trunks of 16 and 12 trees respectively in an orchard of sweet cherries. The trap (Fig. 5) consisted of a cloth sleeve tapering towards its upper end; one side was split, passed obliquely round the tree trunk, and then sewn up so as to girdle the trunk tightly. The apical portion passed through a 2-inch glass tube and was folded back and secured over its top. The tube passed through and was attached to a metal lid fixed to the mouth of an inverted glass jar secured to a lower lateral branch of the tree. Moths, diverted from their upward progress into the sleeve, entered the jar and were unable to escape. They were collected daily by removing the lid from the jar. The number of females taken per day is shown in Figs. 4c and 4d. A total of 920 females and 519 males were trapped in 1952, and 432 females and 132 males in 1953. Females were taken on greasebands from 9th November until 30th December 1951, and from 5th November until 28th December 1952; in traps from 1st November 1952 until 16th January 1953, and from 30th October until 19th December 1953.

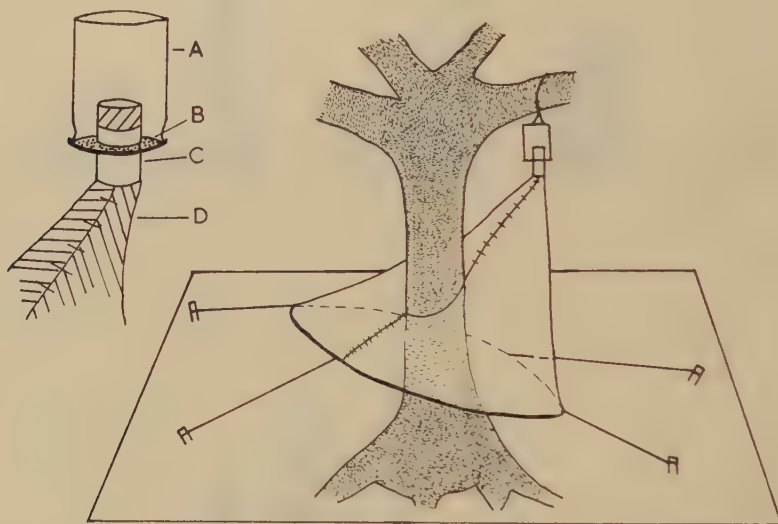


FIG. 5.

The trap used to catch ascending female moths. A, jar; B, lid; C, tube; D, top of sleeve.

In general terms it may be said that there was a peak of emergence of females in cages during the week commencing 18th November 1951, and in the field during the week commencing 2nd December 1951. In 1952, both in the cages and on two field plots, there were two peaks, before and after the week commencing 2nd December, while in 1953 highest numbers were recorded both in cages and in the field during the week commencing 25th November. Apart from the discrepancy in 1951, agreement is good, particularly in 1952 when three methods were used with similar results.

PLATE I.



FIG. 6.

Robinson light trap with anti-inhibition device in place.

When cages in which moths were emerging were emptied at 4 p.m., it was often observed that no more had emerged the following morning; for this reason, the air temperatures shown by the graphs in Fig. 4C and 4D were selected for the period 10 a.m. until 4 p.m. inclusive on the day prior to the emptying of the trap. When temperatures fell below about 35°F. , as in 1952, few female moths were trapped on the night following; when the temperature subsequently rose, very high numbers were caught, as though individuals on the point of emergence had been accumulating during the cold spell. In 1953, when the autumn was mild and temperatures were consistently higher, this effect was less marked.

Flight period of the males. In 1951 a standard Robinson light trap, set up against a mixed wood adjacent to a cultivated field at East Malling, caught Winter Moths on only one night of the year.

In 1952 two light traps were set up, one within a strip of woodland, the other in a field of young pear trees. During the early part of the autumn many moths were seen settled on trees near the trap in the wood, during the night or early morning. It was concluded that they had become inhibited from flight as described by Robinson (1952). A wide-mouthed glass jar partly painted with black paint and resting on the vanes of the trap over the lamp (Fig. 6) served two purposes, to provide an anti-inhibition device similar to that described by Robinson and to weather-proof the lamp, failures of which due to moisture had been rather frequent up to this point. During a trial period of one month when such jars were placed over the two traps for two nights and left off for two nights alternately, 73 *Geometrids*, including 30 Winter Moths, were caught when the device was on and 12, including 7 Winter Moths, when it was off. After 14th December the device was left on permanently. Winter Moths were caught in this season from 18th October until 19th January.

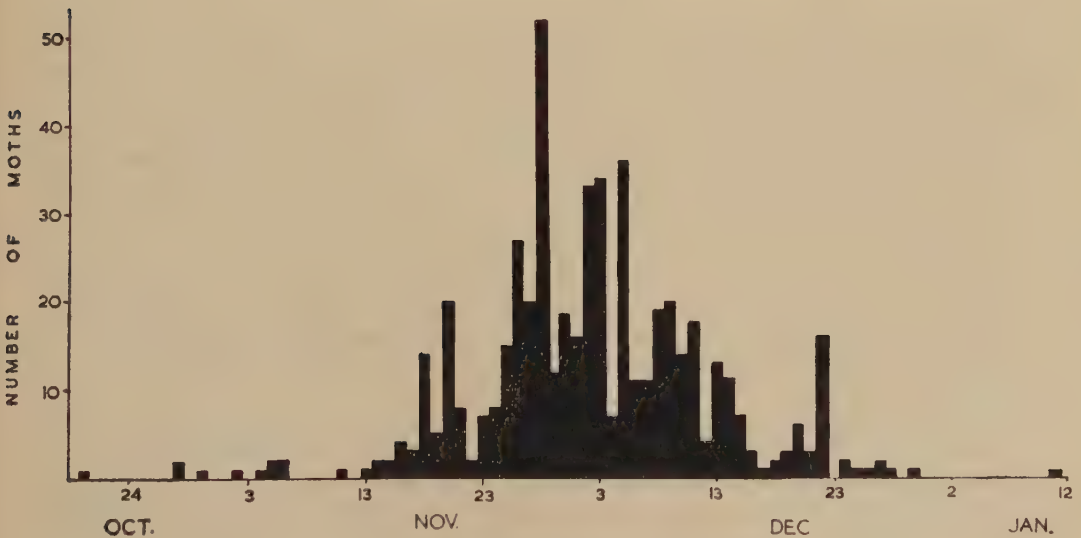


FIG. 7.

The number of male moths caught per day in a light trap, 1953-4.

In 1953 the light trap with anti-inhibition device was set up among oak trees in a wood near East Malling. Five hundred and twenty-eight moths were caught between 20th October 1953 and 11th January 1954, the numbers caught per day being illustrated in Fig. 7. Williams (1936) has shown that moonlight and cloud cover affect the number of moths entering a light trap ; thus conclusions from these data as to the time of greatest abundance must be tentative, but male moths were apparently most abundant near to 1st December.

NATURAL ENEMIES.

During the period under review, though no strictly quantitative comparison is available, it was evident that the population density of adults was much below that of larvae and that much mortality occurred between these stages. Time did not permit of any attempt to investigate the causes of this mortality. In one case, however, when larvae were collected in May 1953 to provide material for records of emergence in the outdoor insectary, after 94 moths had emerged in the autumn of 1953, twelve specimens of the Tachinid *Monochaeta albicans* Fall. emerged in the spring of 1954 between the 2nd and 29th April. No other considerable emergence of parasites was recorded.

ECONOMIC IMPORTANCE AND CONTROL.

The Winter Moth was for many years a serious pest of top fruits. In England, since Ormerod (1884) first suggested the measure, greasebanding was widely used in an attempt to control this insect. Opinions on its success differ, but it is obvious that large numbers of female moths are prevented from laying eggs by its use. Jary (1931) showed that moths could on occasion cross a lower band to an upper one ; Wilson (1924) suggested that moths might cross a band when a film of condensation formed on its surface. However, if bands are kept clean and fresh until mid-April, this measure still has its place in situations such as gardens, or on steep slopes or on trees of great size, where efficient spraying is difficult.

Various forms of arsenate wash have been recommended since Ormerod (1891) first suggested the use of Paris Green. In recent years, greasebanding followed by two applications of lead arsenate against the larvae, or various forms of winter wash against the eggs, failed to control this pest adequately and Massee (1953) stated that in 1939 Winter Moth caterpillars were still considered important pests. At present, the numbers of this pest in well-sprayed orchards are very low ; there seems little doubt that this is primarily due to the use of DDT during the pre-blossom stage. There is, however, no large body of experimental data to support this. Dicker and Briggs (1952) found reductions of from 79 to 89 per cent. after applications of 0.1 and 0.05 per cent. DDT wettable powder, but the experimental plots were only lightly infested.

Massee (1953) made a plea for an ecological study of the orchard fauna and believed that such an approach would lead to reductions and modifications, particularly of timing, in spray programmes. At present, the practice of spraying annually before the blossom period with a DDT insecticide for the control of aphids on most top fruits, with incidental control of any Winter Moth larvae present, means that the question of whether it is necessary to continue this application does not arise. However, should spraying practices in the future change in a way likely to

prejudice Winter Moth control, it would be well to bear in mind that the Winter Moth has a very large number of host plants and that chances of reinfestations may be high in some situations, particularly where woods with tall trees adjoin the orchard, since dispersal from these will occur. Occasional reports of failure to get full control, even with the use of DDT, have usually been associated with this type of site. During the course of the present investigation the author has visited a number of orchards where no sprays have been applied for some years, in some cases as long as twenty, and in one orchard only, in the opinion of the author, has the damage done by Winter Moth and allied caterpillars been likely to cause any considerable reduction in crop. This particular orchard adjoined woodland and the suggestion is that, if at any time in the future reduced spraying programmes are adopted, Winter Moth damage might in many orchards be an occasional rather than a perennial problem.

SUMMARY.

Observations were made from 1951 to 1956 on the Winter Moth (*Operophtera brumata* (L.)). The incubation and hatching periods of eggs were studied in relation to fruit bud development in the field and the laboratory; evidence is presented which suggests that these periods may be affected by the parentage of the eggs. The rate of development of the larvae was also studied; their method of dispersal as young larvae on air currents was demonstrated experimentally. The first emergence of the adults was shown to be unrelated to the incidence of autumn frost; subsequent emergence was delayed by low temperatures. The period over which females emerged in the field and laboratory is defined, and a light trap was used to assess the season of activity of the male. The present status of this insect as a pest is considered.

ACKNOWLEDGMENTS.

This study was directed by Dr. A. M. Massee; Miss S. O. Philcox and Mr. D. K. Brown gave assistance with field records. Mr. J. F. Perkins of the British Museum (Natural History) confirmed the identity of the parasite *Monochaeta albicans* Fall. To those named, and to the owners of various orchards where he was kindly permitted to make observations and erect traps, the author offers his thanks.

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BOOK REVIEWS

CHROMOSOME ATLAS OF FLOWERING PLANTS. By C. D. DARLINGTON and A. P. WYLIE. (London: George Allen & Unwin, Ltd. 1956. Pp. 519, illus. Price 60s.)

The first edition of this work, written by Darlington and Janaki Amal, appeared in 1945 under the title *Chromosome Atlas of Cultivated Plants*. In the present edition this concept has been extended to include the whole of the flowering plants; it embraces nearly 18,000 species, giving the somatic chromosome number and main uses of each. This enormous extension has been achieved, without making the book unduly large, by removing the whole of the original introductory portion. In its stead, a separate volume, entitled *Chromosome Botany*, has been produced by Professor Darlington and this serves as an introduction to the Atlas whilst being in itself a masterly survey of chromosome behaviour and evolution.

The reviewer was surprised to find no reference under *Gossypium* to the Australian species *G. robinsonii*, the chromosome number ($2n=26$) of which was determined by Douwes and Cuany (1952). Also, although the *G. barbadense* varieties *brasiliense* and *darwinii* are given, no reference is made to the *G. hirsutum* varieties *punctatum* and *marie-galante* both of which are $2n = 52$. In this section *G. armorianum* should be *armourianum*. It would, however, be more than surprising if such minor additions and corrections could not be made to a work of this nature.

The second edition of this Atlas will be widely welcomed by all biologists; Professor Darlington and Ann Wylie have performed a task for which geneticists, cytologists and plant breeders will be especially grateful. R.L.K.

EXPERIMENTAL DESIGN AND ITS STATISTICAL BASIS. By D. J. FINNEY. (Cambridge: University Press. 1955. Pp. 169. Price 30s.)

The most difficult and yet the most vital task of the professional statistician is to explain the principles and significance of statistical methods to workers in biology who, in general, have little advanced mathematical training. Dr. Finney's previous books have already established his skill as an expounder of statistical science and the present volume, addressed primarily to research workers in pure and applied biology with the object of making them aware of the potentialities of modern experimental design, will further enhance his well-earned reputation.

The emphasis throughout is on basic principles, and the author wisely eschews the more technical details of statistical theory in favour of a broad logical approach illustrated by numerous examples of the application of the principles under discussion to actual problems in agriculture and clinical medicine. Most of these examples are well chosen and greatly enhance the value of the book; a few, unfortunately, are difficult to follow without access to the original papers, and one in particular (Chapter II, 10) proved incomprehensible to the reviewer and to those of his colleagues (including a statistician!) with whom he discussed it.

One criticism that might be levelled against an otherwise excellent book is that the author is inclined on occasions to drop too readily into statistical jargon. In Chapter III, for instance, a word of explanation as to why the square root of a

variance is sometimes referred to as a "standard deviation" and sometimes as a "standard error" would have been helpful, and on page 20 it is rather surprising to discover that "reducing deviations by a half" means, not dividing them by 2, but subtracting 0.5 from each!

The book is by no means an elementary treatise and, as the author himself admits, the subject is not an easy one. Nevertheless, the biologist with some basic knowledge of statistics should find little difficulty in understanding the first five chapters dealing with such topics as randomized blocks, Latin squares and incomplete block designs. His difficulties will undoubtedly increase in Chapter VI, where he is initiated into the mysteries of fractional replication, confounding and double confounding, and at this point he may well be tempted to abandon the book in despair. This, however, would be unfortunate, for the subsequent chapters on "sequential experiments" and "biological assay" make interesting reading. The final chapter on "selecting a design" is particularly valuable, and few who read thus far will disagree with the author's final conclusion that, to make the best use of modern ideas in experimental design, the biologist needs "access to the advice of a statistical specialist".

L.C.L.

FEATURES OF EVOLUTION IN THE FLOWERING PLANTS. By RONALD GOOD. (London: Longmans, Green & Co. 1956. Pp. 405, illus. Price 30s.)

It is Professor Good's contention that, to an unfortunate and unbalanced extent, evolutionary discussions have been based upon evidence taken mainly from one or two groups of the animal kingdom and that, when the large and important but neglected group, the Flowering Plants, is considered, some of the familiar concepts, such as evolution by natural selection, become very difficult to apply. One reason for this neglect is believed to be the enormous size and diversity of the group, so Professor Good sets himself the task of surveying the whole range of the flowering plants, presenting them "primarily as an achievement of those processes which are called evolution".

An attempt is made to circumvent formal taxonomic groupings with the development of what is called the "stellar analogy", whereby the major groups can be compared to constellations or galaxies possessing spatial distribution. The analogy is convenient and apt, for the more the details of the constellations are resolved, the more they are found to consist of smaller units until, at the end point, individual plants are discovered.

After a general review of the diversity and size of the Angiosperms, detailed attention is paid to two of the more outstanding and specialized families, the Asclepiadaceae and Compositae. The former are chosen because, with their peculiar pollination mechanisms and floral elaboration, they are of particular significance when considered in relation to the hypothesis of natural selection. The Compositae are considered as the most remarkable expression of the phenomenon of pseudanthly, itself an extreme development of floral aggregation, and it is contended that the highly evolved pseudanthium is exactly comparable with the simple flower of such a plant as *Anemone*, with consequential reflections upon the vexed questions of "primitiveness" and "direction" in evolution.

To survey so large and diverse a group as the Flowering Plants and to extract detailed evidence from the range of morphological specialization in such a family as the Asclepiadaceae is no small undertaking and, although perhaps in an attempt to remain concise, the reading is at times difficult, Professor Good succeeds remarkably well. However, most readers will have had little previous knowledge of the predominantly tropical Asclepiadaceae or, to some extent, of the larger Compositae, and their imagination will be considerably taxed when following the accounts of these groups. One feels that the strain could have been lessened if more illustrations had been given, and this despite the fact that the various divisions of the Angiosperms are depicted by means of some 94 full-page drawings, and numerous smaller figures are presented to illustrate the Asclepiadaceae and Compositae. If space then became a problem the full-page drawings could be equally well depicted at half or quarter size, without any diminution in their value, as is shown by the otherwise identical figures 32 and 142.

But to return to Professor Good's object, that of drawing attention to the Flowering Plants and the evolutionary significance of many of their aspects ; despite the difficult task, and even though many of the points made are debatable, the book should nevertheless succeed and is recommended to all biologists interested in general evolutionary problems whatever their normal specialization.

P.S.G.

DISEASES OF FRUIT CROPS. By HARRY WARREN ANDERSON. (New York : McGraw-Hill Book Co. Inc. 1956. Pp. 501, illus. Price \$8.50.)

The appearance of this text-book from the United States of America, within a year of the publication of the third edition of " Diseases of Fruits and Hops " by the late Dr. H. Wormald, challenges comparison of these, the two major works now covering this particular field of crop pathology.

The general arrangement of the two books is similar, the diseases being treated under the main botanical groupings of the host-fruits, i.e. pome, stone fruits, etc. The treatment of the diseases themselves, however, differs markedly in the two works. Wormald's is primarily designed to provide the intelligent British fruit grower with a key to the diagnosis of the diseases in his orchard, and its multitude of excellent photographic illustrations is consequently a leading and integral feature. Professor Anderson, an equally well-known specialist on this group of crop diseases, has on the other hand written a book on the corresponding American scene, evidently intended primarily as a text-book proper for the student of plant pathology and for the advisory fruit pathologist wanting to be initiated into the background and fundamentals of each of the major diseases described. The emphasis here is on documentation, etiology and control rather than on diagnosis, and the illustrations are small, sparse and not of comparably superlative quality.

The work consists of thirteen large chapters starting with an excellent introductory survey of the field of fruit pathology in which the author bases his material on a very broad definition of plant disease, not only embracing parasitic and functional diseases but such disorders as spray injury and nutritional deficiency and unbalance. To the diseases caused by plant parasites he also adds those due to parasitic nematodes, with every justification in the present reviewer's view, as having a greater affinity with the micro-plant pathogens than with the insect pests,

in virtue of their susceptibility to similar pure-culture methods of isolation and study. The classification of directly induced phenomena, such as spray injury, as diseases might on the other hand be regarded as having comparable justification to regarding the effects of a punch on the nose as a human disease! Actually in the body of the book, however, the great bulk of space is given to the parasitic and functional diseases, and very little to the other categories mentioned.

The remaining twelve chapters are devoted to summaries of present-day knowledge of the specific diseases of the pome fruits (4), drupe or stone fruits (2), brambles (including raspberries), grapes, strawberries, gooseberries and currants, cranberries, and blackberries.

Each of these sections is prefaced by an excellent introduction to the host fruits themselves. Then the diseases are dealt with individually under such headings (to take Apple Scab as an illustration) as history, geographic distribution, economic importance, causal organisms (host range and morphology), disease cycle, relations to environment, and control, concluding with an author-list of select references to original papers on the disease, some of which have been referred to in the preceding text. Where a particular disease occurs on more than one fruit crop the full description is attached to the economically most important one, with cross references under the other hosts. An excellent index concludes the work, comprising primarily references both to the common names of the host fruits and to the Latin binomials of the pathogens as well as to general topics such as soil disinfection. The common names of the diseases are only listed as sub-references under the names of their appropriate hosts.

Any text-book of any branch of the new and rapidly advancing applied science of plant pathology must be expected to be somewhat out of date on publication but, even with such an allowance, the present book, published in Great Britain in 1956, is very uneven in this respect, being very much behind the time in some of its sections and advanced in others. For instance, the most recent of the references to the section on bacterial canker and gummosis of the stone fruits (p. 249) is a paper published in 1939, thus omitting all reference to the considerable advances in our knowledge of the seasonal cycle of these diseases from the recent researches of J. E. Crosse and others. On the other hand the strawberry disease section (Chapter 10) in which field the author is himself a well-known authority, is reasonably up to date with references as recent as 1953.

Such minor criticisms, which can readily be met in future editions, in no way detract from the comprehensive and workmanlike qualities of this survey of the field of hardy-fruit diseases as a whole, and it can be confidently recommended to students, advisers and others as a reliable and excellently planned and presented introduction to, and usable handbook on, this interesting group of crop diseases.

R.V.H.

MODERN COMMERCIAL FRUIT GROWING. Edited by T. WALLACE and R. G. W. BUSH. (London: W. H. & L. Collingridge Ltd. 1956. Pp. 384, illus. Price £5 5s.)

This book is unique in that it collects together for the first time the work of so many experts and scientists in the many aspects of fruit growing. Under the joint editorship of Professor T. Wallace and Raymond G. W. Bush, the grower, the

scientist, the administrator and the student are presented with the most up-to-date factual knowledge in a form which any who can read can not only understand with profit, but enjoy with pleasure.

Many will ask—why produce such a book? Fruit is difficult to sell already and if everyone becomes a first-class fruit grower by applying the knowledge so ably set out, we shall have an annual glut of fruit. True, the problem of production as such is almost *solved*—how to produce cheaper is far from solved, but the first steps are indicated in the book. The problem of consumption is far from solved, namely to raise the consumption per head, to extend the marketing season (the book deals with this), to regulate imports to correlate with home production. The latter is not only a political but also a physical problem, and as such must be solved by political methods and possibly by another book on the lines so amply demonstrated in this book.

Raymond Bush, with his bitter experience of growing in a frost site in the West Midlands followed by his development of a frost-free site, and later as a consultant in all parts of England is no doubt the expert to write the chapter on climate and site. Professor Wallace follows on soils for fruit growing. Great director of a great research station that he is, one is apt to forget that his main work was the study of soils and his influence on fruit growing has been, is, and will be profound in this matter. Here he sets out the highlights of a lifetime's experience in one chapter. This is followed by Dr. C. Bould on the mineral nutrition of fruit crops, cultural systems and manuring, a subject which increases in importance at the same rate as the grower "flogs" the trees to produce more and more. Mr. F. A. Roach writes, in three separate chapters, on planting material, planting systems and tree forms, and strawberries. His acute power of observation and gift for expressing himself are of great value.

The chapter on modern fungicides and insecticides by Dr. Hubert Martin, who was at Long Ashton Research Station for many years and is now at London, Ontario, is one of the most brilliant text-book chapters the reviewer has ever read. A dull subject to some, so often coloured by someone who has something to sell, is here set out with accuracy, interest and, last but by no means least, humour. One's trust in his knowledge is strengthened by the fact that he does not claim to know all the answers, but at least he can take the reader farther along the path of wisdom on the subject than any other writer in a most pleasant way.

Dr. H. G. H. Kearns writes a chapter on machinery which might easily be headed "Automation in Fruit Growing". He and his colleagues have done as much as anyone to save labour which after all is at least 40 per cent. of the costs of production.

Mr. E. W. Hobbis on the planning of fruit growing projects can be read with much profit by the intending grower, possibly with pain by the existing grower. It is so difficult to undo our mistakes in this field.

Mr. J. M. S. Potter contributes his wealth of experience, as Director of the National Fruit Trials, in a chapter on varieties and rootstocks, and a later one on new varieties of fruits. I should have liked these two chapters combined—better still a Potter's Pomona in a separate book. It seems time that a new British Pomona should be produced. We have had nothing since the Herefordshire Pomona of 1885. Is there anyone who will come forward as a patron and give Mr. Potter full support to publish such a work?

Mr. R. C. Thompson contributes on pruning and there is little doubt that the

policy of pruning he has so often advocated will be further strengthened by this chapter.

Messrs. N. G. Morgan and R. W. Marsh of Long Ashton contribute on the control of pests and diseases and the writer, having carried out the programme of the spray calendar for the past four years, has no hesitation in recommending its adoption.

Mr. J. F. Goaman, who has recently retired from the Marketing Division of the Ministry of Agriculture after a lifetime's experience, writes on the harvesting and marketing of tree fruits. A study by growers of the past, present and future marketing arrangements would be worth while. Though he does not say so directly, the big problem for the future will be not only grading and marketing, but publicity to increase consumption.

Dr. J. C. Fidler writes on fruit storage—where this country has not only pioneered, but the work of Ditton has saved the industry from collapse by spreading the marketing season.

Part Three is devoted to soft fruit production with chapters by Messrs. E. W. Hobbs, N. H. Grubb and F. A. Roach. Mr. Grubb's chapter on raspberries is notable. His new varieties of raspberries bred at East Malling Research Station have been of the utmost value to the industry.

Finally, we have three subjects of special interest, the genetics of fruit breeding by Mr. M. B. Crane, possibly the only Fellow of the Royal Society with no university degree; surely the greatest distinction! To refer to a man as a genius should be sparingly done, but Mr. M. B. Crane is a genius and he has done more with new fruit varieties than any other man since Thomas Andrew Knight. His influence will be felt by future generations.

Then we have the end chapters by Drs. L. C. Luckwill and C. H. Cadman, particularly on virus diseases of fruit. These are of the utmost importance—so often the unseen enemy in our midst. Every year new virus diseases seem to appear in combination or singly and the whole future of the industry depends on healthy, vigorous stocks.

Finally, a chapter on growth regulators by Dr. Luckwell brings to an end this wonderful book.

May it have a large circulation, especially among growers, among scientists, among students. Here is a reference book and encyclopaedia combined. Priced at five guineas it is not an unreasonable amount to pay for the up-to-date information contained. While it refers to British conditions, much of the information would apply wherever fruit is grown. There has been nothing quite like it since Auchter and Knapp published "Orchard and Small Fruit Culture in the U.S.A." in 1937—and much has happened in the past twenty years.

C.P.N.

VEGETABLES FOR GARDEN AND EXHIBITION. By S. M. GAULT. (London : W. H. & L. Collingridge Ltd. 1956. Pp. 268, illus. Price 50s.)

Many horticultural scientists are also amateur gardeners and for this reason we occasionally notice books that may be of interest to them. While some concentrate their energies on flowers or fruit, many, particularly those that have families, try to grow their own vegetables with varying success. All would like to turn to a reliable book on gardening from time to time. This is one of the best and most up-to-date

books on vegetable gardening we have seen for some time ; it is also expensive. Nevertheless, though he may not be very interested in exhibitions, the practical gardener of to-day will find so much information of value to him here that we can recommend it unreservedly, the more so because it does not confine itself to the laborious and expensive methods that are now old-fashioned, but describes methods that any keen gardener can carry out if he takes the trouble. This reviewer will keep it near at hand and hopes that in future it will enable him to combat some of the many troubles that have beset him in the past.

T.N.H.

PUBLICATIONS RECEIVED.

THE USE OF LIME IN AGRICULTURE. Ministry of Agriculture Bulletin No. 35. (London : H.M. Stationery Office. 1956. Pp. 53, illus. Price 3s. 6d.)

WATERCRESS CULTIVATION. Ministry of Agriculture Bulletin No. 136. (London : H.M. Stationery Office. 1956. Pp. 28, illus. Price 2s. 6d.)

ROYAL HORTICULTURAL SOCIETY

THE JONES-BATEMAN CUP FOR RESEARCH IN FRUIT GROWING

The Jones-Bateman Cup, presented by Miss L. Jones-Bateman, of Cae Glas, Abergele, in 1920, for the encouragement of fruit production, is offered for award triennially for original research in fruit culture which has added to our knowledge of cultivation, genetics, or other relative matters. The Cup is offered for award in 1957.

Candidates should submit accounts of their work by 31st October. The work dealt with should have been mainly carried out by the candidate in the United Kingdom and mostly during the last five years. The Cup will be held for three years by the successful candidate, who must give a bond for its safe return. The holder will be able to compete again on the next or any succeeding occasion. When the Cup is relinquished the holder will receive a Hogg Medal. The Assessors will be three (two appointed by The Royal Horticultural Society and one by the National Farmers' Union), and they will report to the Council of the Society upon the originality and comparative potential value to the fruit-growing industry of the work of the candidates.

The Jones-Bateman Cup has been awarded as follows :

- 1930 — Mr. M. B. Crane.
- 1937 — Dr. W. A. Roach.
- 1945 — Dr. W. S. Rogers.
- 1948 — Dr. A. Beryl Beakbane.
- 1951 — Not awarded.
- 1954 — Mr. R. Barrington Brock.

A. SIMMONDS, *Secretary*.

Vincent Square,
Westminster, S.W.1.

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1. The *Journal of Horticultural Science* is an official organ of the Horticultural and Agricultural Research Station, Long Ashton, Bristol, and the Horticultural Research Station, East Malling, Kent.

The Publication Committee welcome horticultural papers from all other sources.

2. All manuscripts should be in double-spaced typewriting, with a good margin, and should be addressed to the Editors, East Malling Research Station, near Maidstone, Kent, England. Papers must be written concisely. Historical reviews should be as short as possible and only such references to literature as bear directly on the subject should be included. Tables and illustrations, if any, must be only such as are absolutely essential for clear presentation.

3. Authors of papers containing extensive numerical observations should consult the recommendations of the British Association Committee on Biological Measurements, 1927, obtainable from Burlington House, London, W.1. Price 6d. Arrangements have been made whereby original data too extensive for complete publication may be deposited at the British Museum (Natural History), London, S.W.7, or with the Royal Society of Edinburgh, 22 George Street, and thus be available for consultation by other workers. Full bibliographical reference to the publication in which the results are summarized must be supplied with the data.

4. Each paper must conclude with a concise and critically correct summary of its actual content. It should contain any new or verified constants as well as any other critical data of permanent value but not tables or graphs. Any organism mentioned should be given its scientific name.

5. Where a paper is of a highly technical nature it should be preceded by a brief synopsis, in which its contents are simply and clearly stated for the benefit of non-technical readers.

6. References to literature may be by numbers (in brackets) in the text corresponding to a numbered list at the end of the paper or by the Harvard system (author's name and date of publication). By either method, the papers cited should be listed alphabetically according to authors' names, followed by the date of publication. The title of the paper should next be given in full, followed by contracted, but strictly intelligible, title of source of publication, the volume and page numbers. Authors are responsible for the accuracy of their lists of references and should check them carefully in both typescript and proof.

7. The scientific names given in the "List of Common British Plant Diseases", published by the British Mycological Society (Cambridge University Press, 1944) and "Common Names of British Insect and other Pests", published by the Association of Applied Biologists (The Mendip Press Ltd., Bath, 1947) must be employed.

8. Authors in this country will be supplied with slip proofs of their papers; these they should correct with care immediately on receipt and return without delay, together with the original manuscript. Page proofs are not usually supplied to authors. Typographical errors, if any, should be corrected; small verbal alterations are permissible but substantial changes may not be made. Overseas authors should be willing to accede to editorial treatment of their contributions, if necessary, limited to methods of presentation, and leave proof correction to the Editors.

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HORTICULTURAL ABSTRACTS

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